CAHNERS PUBLICATION

AUGUST 5, 1974

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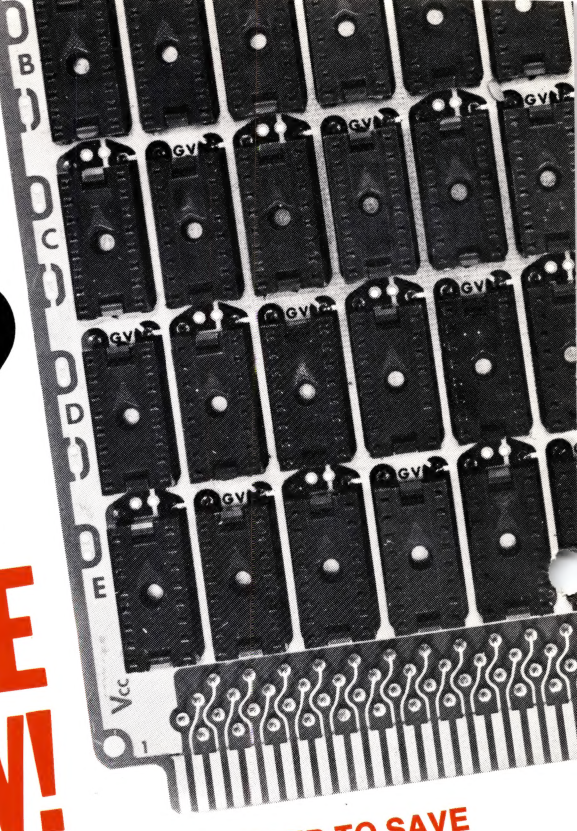
EDN

XCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

The what, why and how of dual-beam oscilloscopes

Designers' guide to: Software for the hardware designer

GET THE MOST OUT OF HIGH POWER SEMICONDUCTORS



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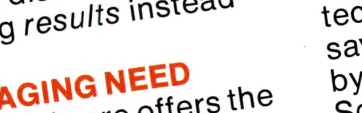

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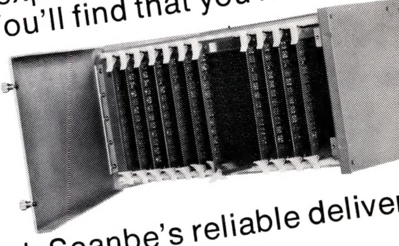

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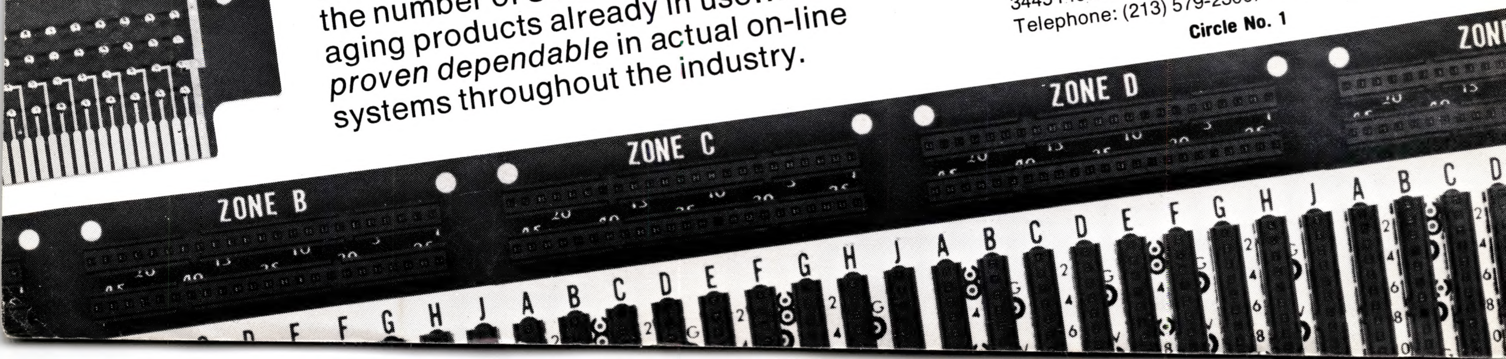

AUGUST 5, 1974
VOLUME 19, NUMBER 15

EDN

EXCLUSIVELY FOR DESIGNERS AND
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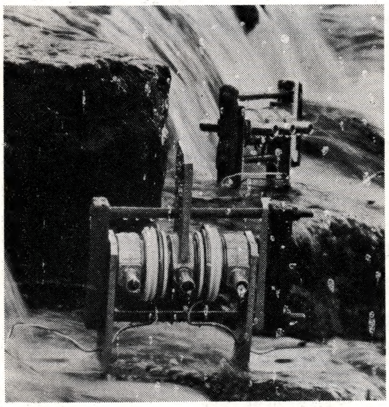

COVER

By the bubbling waters stood — water-cooled disc semiconductors? Seriously, just as a cool dip in a stream can "save your life" (or so it seems) on a hot day, so water cooling can greatly extend the life of power semiconductors. It also enables you to design more efficient systems. Westinghouse Electric Corp. manufactures the assemblies shown; the related story begins on pg. 36.

DESIGN NEWS

LCLV generates colors for projection systems 12
Is sensitivity breakthrough the key to low-cost CW laser detectors? . . . ESFI technology adds on-chip decoders and nearly bipolar speeds to MNOS memories . . . Winners in EDN's 3rd Annual Creative Design Contest . . . Liquid bubbles could be the key to low-cost graphic displays.

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Are your power-semiconductor designs sub-optimized? They won't be if you consider all the factors detailed here.

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Known as dual-beam, dual-gun or split-beam, these special-purpose oscilloscopes are important design tools — if you understand them.

Software for the hardware designer — Part 2 51
Programming microprocessors is not as easy as you might expect. Here's the way to program at least one popular type.

Do you have what it takes to be an EFFECTIVE engineer? 59
Ineffective engineering represents a horrendous and needless waste of valuable talent. Here is how to increase your effectiveness.

Designers' Rountable on low-power logic — Part 2 69
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Computer Demographic Edition 34A-L

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"When engineers saw they didn't have any knobs, they were scared they'd lose control, but now they're in love with the thing."

So happy, indeed, that when AMI offered to brief our people on their side of the story, we asked if we could publish some of their comments. They're reproduced here.

The validity of their comments? Each uses Sentry 600, relies on Sentry 600, and has one or more Sentry 600 systems in their department: Ed Carcher, Manager of Product Characterization; George Gray, Manager, Test; Bill McNeally, Supervisor, Test; Bob Frohman, Supervisor, Systems Software Support; Fred Jenne, Director of Advanced Product Development.

"You'd need a wall full of knobs to let them do slowly what S-600 does fast."

"We have yet to find a device we couldn't test on the Sentry 600."

Slightly over a year ago, American Microsystems, Inc. ordered their first Fairchild Sentry 600.

Today, nine Sentry 600's are on line at AMI. Number ten is on its way. Each system was carefully evaluated by AMI. And then the next ordered. The result? AMI is now the largest purchaser of Fairchild's Sentry 600. It's a happy association.

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"One insertion goes through 50 different tests — we are checking parameters, not making Go/No-Go tests."

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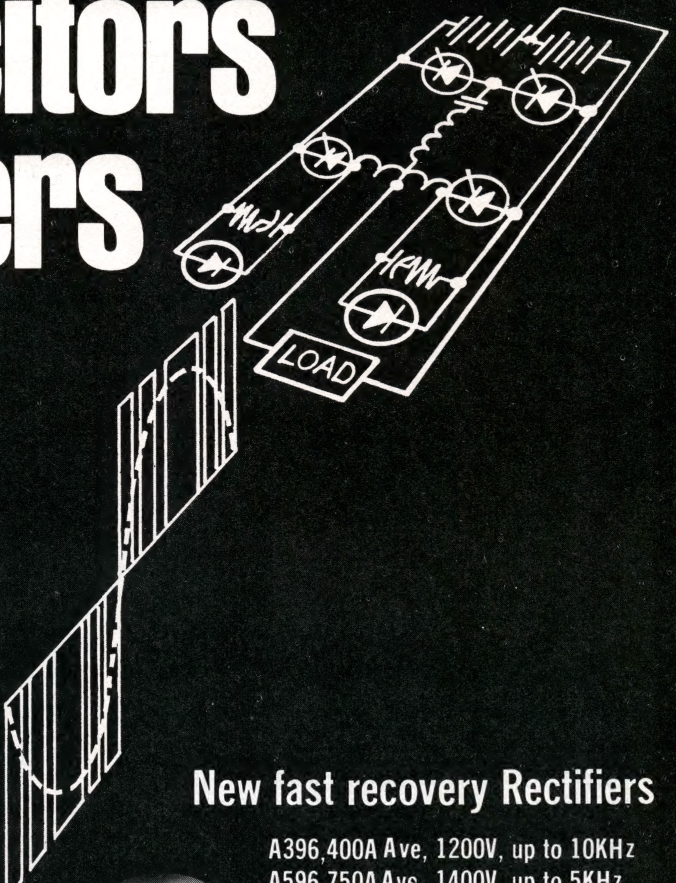
Circle No. 6

Thyristors, Rectifiers and Capacitors for Inverters



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C509 SWITCHES 1000A pk @ 5KHz

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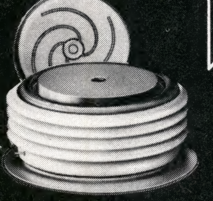
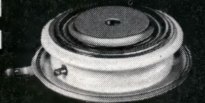


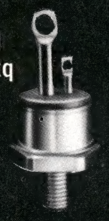
C364,275A RMS, up to 600V, 10 μsec tq
C365,275A RMS, up to 600V, 20 μsec tq

For high speed, low-loss power switching in 1-10 KHz range.



C149,63A RMS, up to 600V, 10 and 20 μsec tq
C148,55A RMS, up to 1200V, 30 and 40 μsec tq

15° C cooler operation than competitive types at same case temperature; ¼"-28 stud mount package.



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A596,750A Ave, 1400V, up to 5KHz

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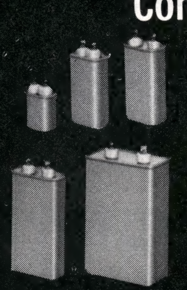

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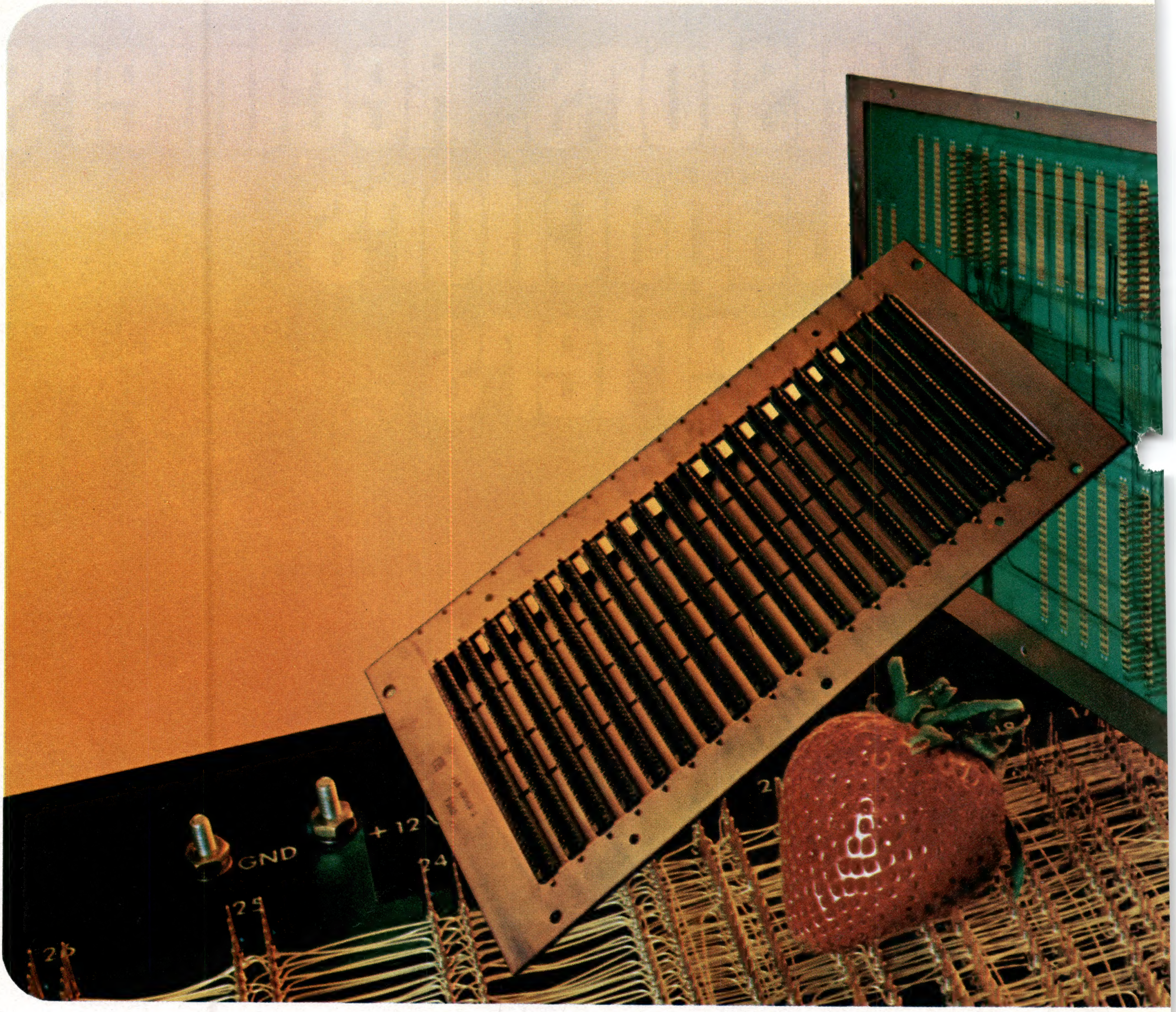

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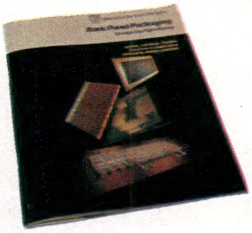

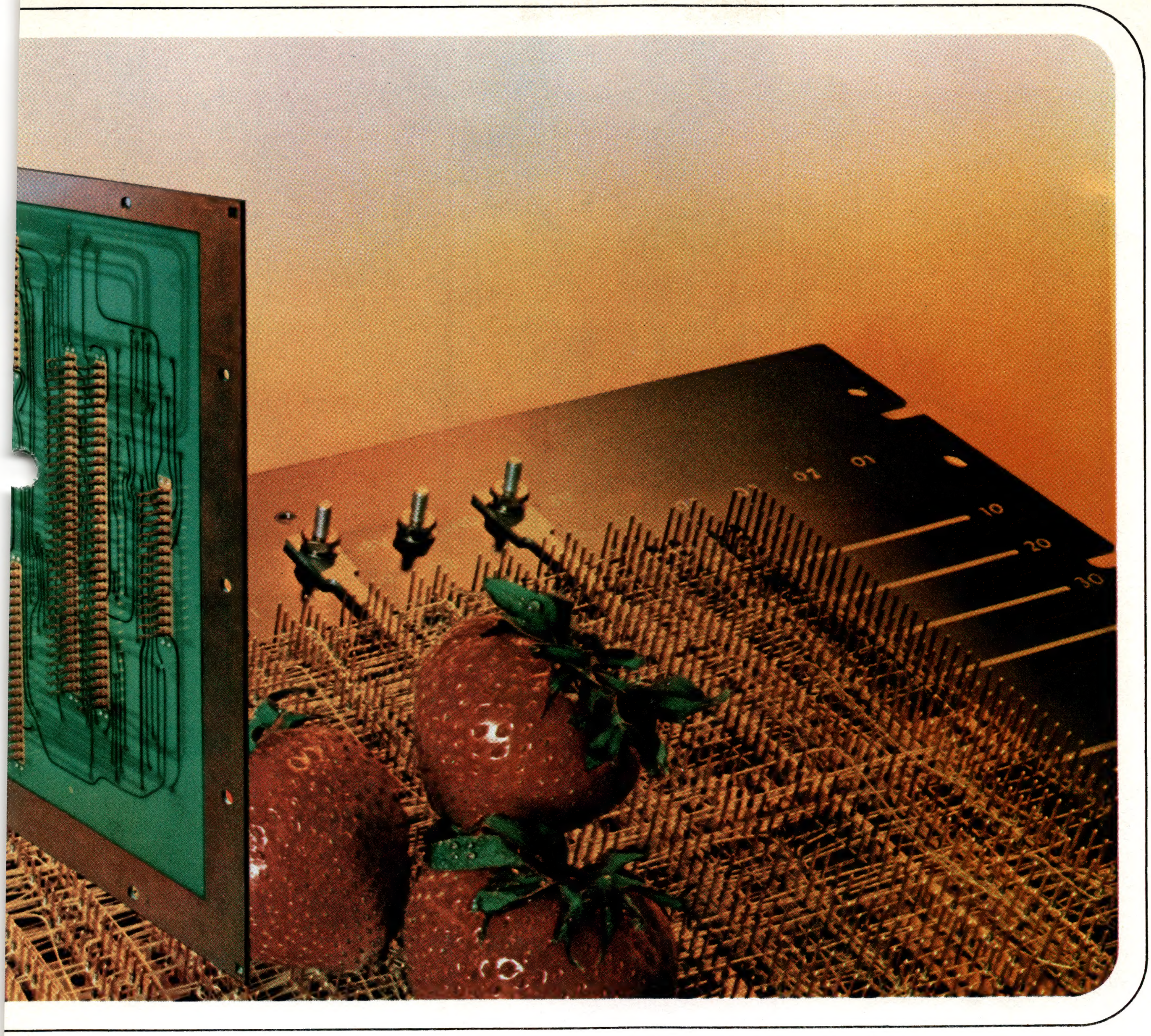

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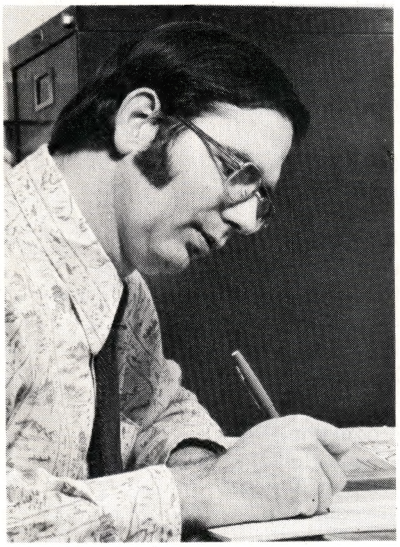
EDITORIAL



The other side of the coin

Elsewhere in this issue, "Do you have what it takes to be an effective engineer?" touches on a subject of which I am very sensitive: the value of human resources and the effective use thereof. The article presents, in a positive way, the characteristics of engineers who are dynamic influences in their personal and corporate environments.

But there's another side to the coin. Industry too often fails to use even effective engineers effectively. I'm sure you know what I mean. For example, as hard as you try, often there's no way you can get a technician assigned to your project. So you end up building and testing the design yourself. Likewise, you frequently can't get cooperation from purchasing, so you order your own parts. Keep in mind I'm talking about organizational ineffectiveness, not personal ineffectiveness.

Such a waste of talent borders on being criminal. Criminal from the traditional business sense because the resulting productivity is excessively low (the best engineers do not make the best technicians); and criminal from a human resources standpoint because either the company loses its good people, or those good people who stay become ineffective and disillusioned (effectively sabotaged) individuals.

How many technicians can a good, effective engineer support? Depending on the circumstances, isn't it probably anywhere from one to six? How many work for you? If the ratio is inadequate, doesn't it make you angry? (Especially with an engineering "shortage" currently being reported?) If so, what have you done about it? What happened?

We'd like to know the answers to these questions. EDN believes engineering should be an effective, meaningful and professional occupation. If you agree, write us. We will combine your ideas into an article entitled "Guidelines for the effective employer." Watch for it.

Walt Patstone

Walt Patstone
Managing Editor

Which Heinemann overvoltage protector should watch over your electronics?

Below 5 amp dc Our tiniest hybrid (a thick-film microcircuit) packs a sensing amplifier, control circuit, and SCR "crowbar". When voltage equals the protector's rating, the SCR fires, shunting the load to ground in 500 nanoseconds—before any damage can be done.

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SDT-96304-06	TO-3	80-325V	10V	100A	10 min @ 70A, 5V	10 MHz	
SDT-13301-05	TO-3*	300-500V	5V	20A	10 min @ 5A, 5V	15 MHz	2.2 μs
SDT-12301-03	TO-3*	200-300V	5V	20A	10 min @ 10A, 5V	25 MHz	1.6 μs
SDT-85301-10	TO-3	40-150V	8V	10A	40 min @ 5A, 5V	40 MHz	
SDT-85501-10	TO-39	40-150V	8V	10A	40 min @ 5A, 5V	40 MHz	
SDT-85601-10	TO-66	40-150V	8V	10A	40 min @ 5A, 5V	40 MHz	
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SDM-20301-04	TO-3 Steel	40-100V	5V	15A	1000 min @ 5A, 5V	20 MHz	3.0 μs
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SDM-20321-24	TO-3 Steel	40-100V	5V	20A	750 min @ 10A, 5V	20 MHz	3.0 μs

* TO-61 Isolated Version also available.

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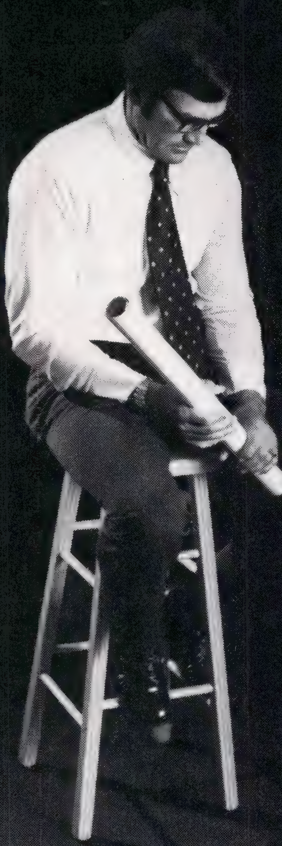
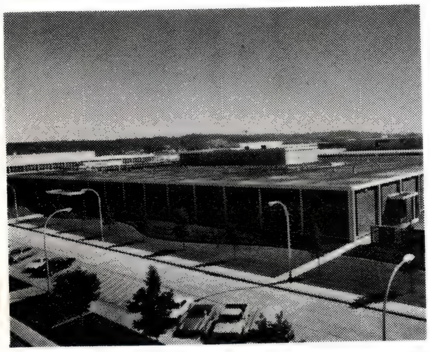
Circle No. 22

Are you all alone with a hybrid circuit problem?

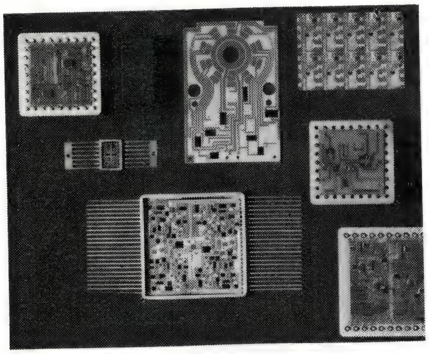


Relax. You have some friends at Boeing.

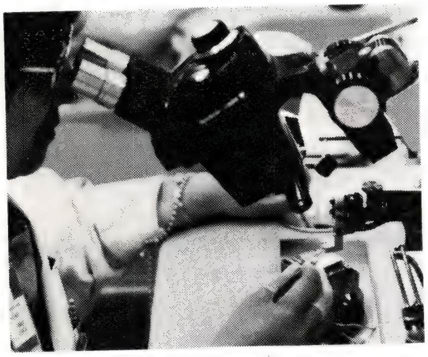


If you're trying to figure out the trade-off between pc's and hybrids, Boeing specialists can provide prompt, precise answers. Or, if you've never specified hybrids, Boeing can help and put your mind at ease. More than 150 people are engaged in this activity at the Boeing microcircuit facility near Seattle.

Boeing has a tremendous investment in hybrid capability. We're in this business to stay. For example, few manufacturers in the business can match the quality and throughput capacity of the Boeing thick film facility. And when it comes to laser trim systems — we have three for resistor trim.



Boeing does just about everything that can be done in hybrids — precision thin film, multilayer thick film, high volume commercial circuits and complex high rel circuits. We go full tilt for customers who've never used hybrids. And we've always been a consistent performer for some of the largest accounts around.



Every step of the way, your order is processed with care and dedication to absolute perfection. This attitude prevails throughout the entire Boeing organization. It's true in building the giant 747s, the Lunar Rovers that went to the moon and in every phase of hybrid circuit production.

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Title____________________________

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Liquid crystal light valve generates colors for projection systems

Erwin Vodovoz, West Coast Editor

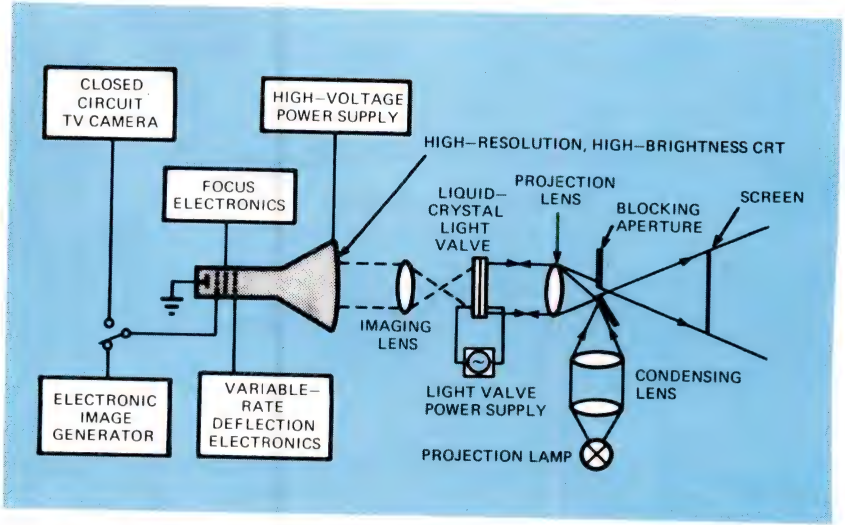
Progress on the liquid-crystal light valve (LCLV) has developed to the point where it can produce a black on white, white on black, or a 4-color display. Its initial development was first reported at the 1972 International Electron Devices Meeting (EDN, February 5, 1973, pg. 17). The device, developed at the Hughes Research Laboratories in Malibu, CA, provides a 5-ft screen via a projection system. First use of the LCLV will be a symbology display for a Navy tactical command data system.

System operation is shown in **Fig. 1**. In this case, the data to be shown comes from a CRT whose source is a TV camera or electronically generated characters. Slides may also be used with a low-power light source such as the raster from a CRT.

To be able to modify the display between black on white and white on black, the blocking aperture (**Fig. 1**) is replaced with two polarizing filters. Rotation of these filters causes reversal of the display.

What makes it tick?

Heart of this system is the liquid crystal light valve shown in **Fig. 2**. Operation of the device can be thought of in terms of two resistors, R_L and R_P, in series with a voltage source V (**Fig. 3**).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VARIABLE–RATE DEFLECTION ELECTRONICS
PROJECTION LAMP

Fig. 1—Versatile LCLV system can project slides, TV or an electronically-generated display.

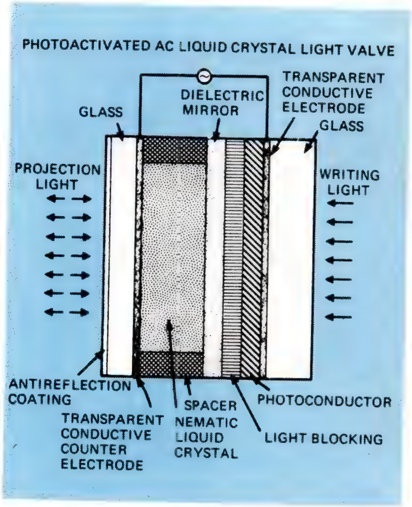


Fig. 2—Liquid-crystal light valve construction makes use of thin-film technology and nonexotic materials. Production should be easy.

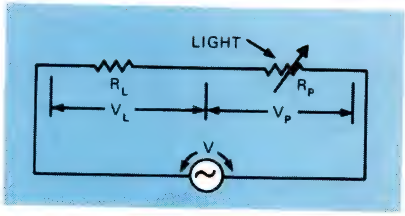


Fig. 3—Equivalent circuit of the LCLV is shown for low frequencies. As the bias frequency goes up, the photoconductor becomes capacitive, reducing the range of colors.

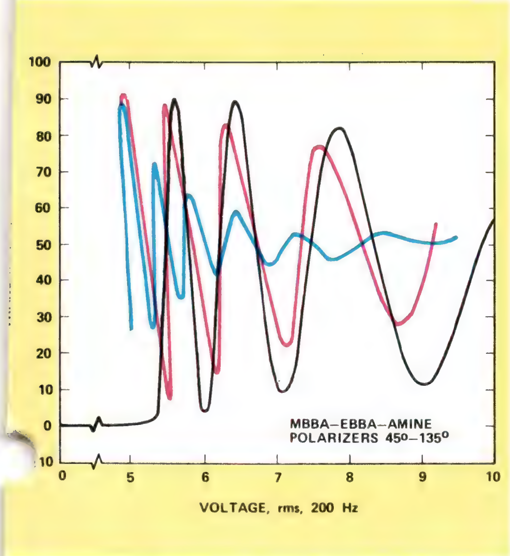


Fig. 4—Color vs. voltage characteristics of the LCLV is what allows this device to produce color or black and white.

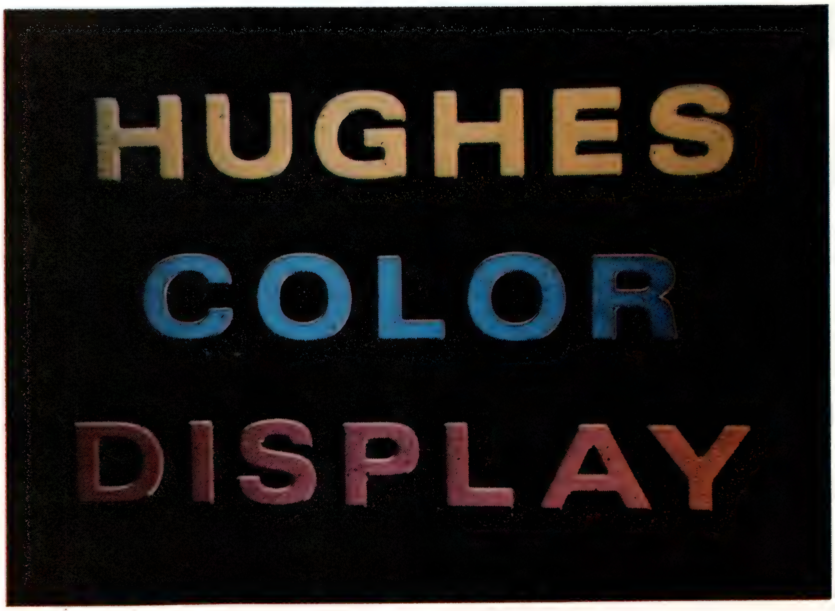


Fig. 6—Three colors plus white are available with the present LCLV. A good deal of work must be done to use this device for a color projection system.

R_L is the resistance of the liquid crystal and R_P is the resistance of the photoconductor. When an ac bias voltage is applied to the transparent conductive electrodes, a voltage is developed across R_L and R_P. When light is then applied to the photoconductor, the value of R_P changes, causing a change in the voltage across the liquid crystal.

This changing voltage is the key to the LCLV's flexible operation. **Fig. 4** shows the effect on the liquid crystal and the resultant color or shade of gray as a function of this changing voltage. Four colors or seven shades of gray are available due to this mechanism.

Within the system, the LCLV operates like a triode. Data coming from a relatively low-level light source modulates the projection of the high-level light.

The hard facts

Voltage levels on the LCLV range up to 12V and the current level is in the hundreds of μA. Power levels are therefore in the mW range.

The frequency of the bias voltage ranges from about 30 Hz to 500 kHz. At the low-frequency end more voltage develops across the photoconductor. When using a high frequency, there is less range of color, but the resolution is better, decay time is shorter, and the device has better operating sensitivity.

Light power levels required for the early LCLV were about 500 $\mu W/cm^2$. With improvements in film deposition and polishing techniques, as little as 3 $\mu W/cm^2$ are now required. Also, the lifetime of the first LCLV was fairly short. Changing from dc to ac and isolating the photoconductor from the liquid crystal has solved that problem. Units built in a laboratory environment without the benefit of clean-room purity have now been operating for a year with no degradation.

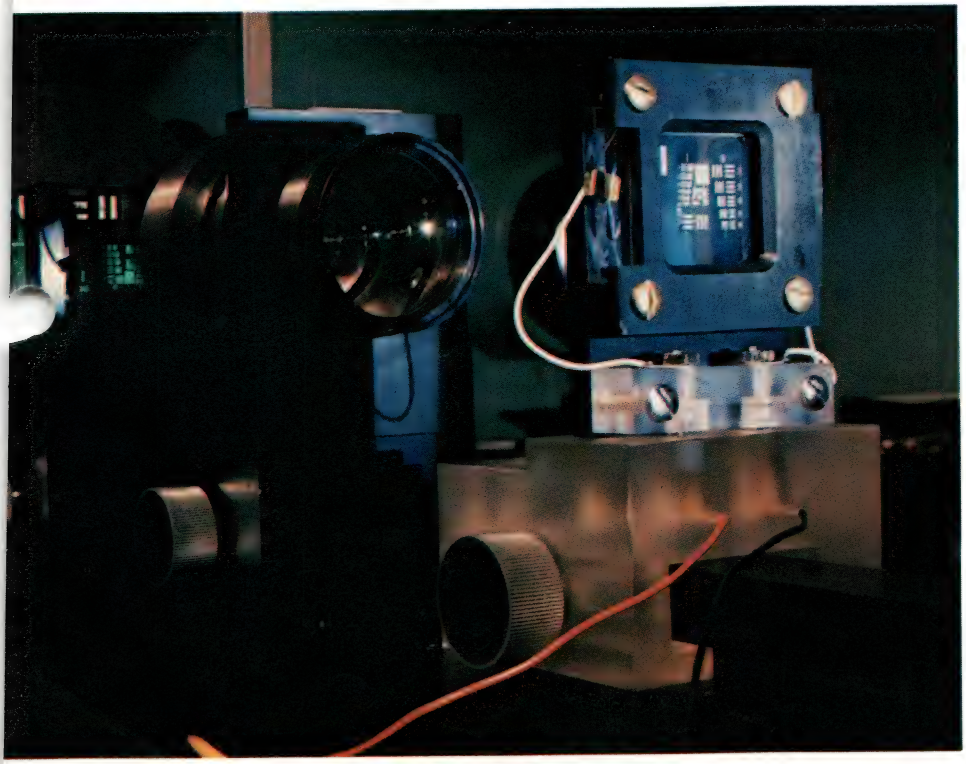


Fig. 5—Resolution testing is shown above in a laboratory system. LCLV is on the right and the green pattern on the left is a slide.

In the area of resolution, 1500 lines/in. have been achieved. With controlled production techniques, it should be possible to maintain this resolution.

Temperature operating range is 10 to 60°C. 40°C is the typical operating temperature in the lab with high-intensity light on the LCLV.

One major advantage of the LCLV is that it uses noncritical materials and proven technologies, therefore production costs should be low. A laboratory model is shown in **Fig. 5** and a sample of colors available can be seen in **Fig. 6**.

Where to from here

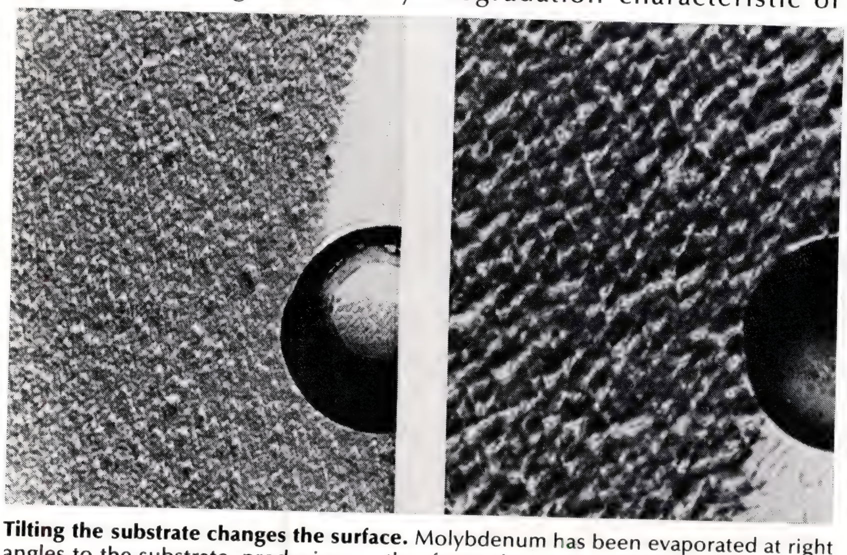
Beyond the first symbology projection system, NASA is looking at this device for use in a data processing system to be installed in a satellite. Using a light intensifier, starlight will be used to excite the LCLV to obtain the required data. It can also store an image, making the LCLV's use as a frame grabber possible.

Greatest potential for commercial use appears to be in the area of color TV projection. For really large-screen color TV, a projection system is required. Developers of the LCLV feel this component has an excellent chance of filling such a need, but much work is still required. That research is now in process. □

Is sensitivity breakthrough the key to low-cost CW laser detectors?

Sensitivity of a laser-induced electrical effect in molybdenum films has been increased by about 1000 times in recent studies at IBM's Thomas J. Watson Research Center in Yorktown Heights, NY. As a result, long laser pulses and even continuous (CW) laser light have produced voltages in the plane of suitably prepared film. These findings by R.J. von Gutfeld and H.L. Caswell support predictions of such behavior made some months ago at the time of the original discovery by Dr. von Gutfeld and E.E. Tynan.

The significance of the new heightened sensitivity is considerable. Promise now exists for inexpensive arrays of versatile laser photodetectors responsive over an extremely broad range of laser pulse lengths (from nanoseconds to CW) and wavelengths (the entire visible spectrum). They also will operate over a wide temperature range (about −160 to +400°C), thus overcoming the heat-degradation characteristic of silicon-based photodetectors. In fact, molybdenum films actually become more efficient at hotter ambients.



Tilting the substrate changes the surface. Molybdenum has been evaporated at right angles to the substrate, producing a rather featureless surface (**left**). By contrast, the columnar growth of surface (**right**), achieved by using slanted deposition (70° from the perpendicular to the substrate), enabled Drs. von Gutfeld and Casell of IBM Research to generate electrical voltages with lower incident power and with long-pulse and CW laser light. In each photo, a 1/2 micron latex sphere shows scale.

Deposition angle critical

The output voltage of the film is due to a temperature gradient induced by incident laser light. A significant difference in temperature exists between the two sides of the film because heat is continuously conducted away from it by its supporting substrate. This fact, which has been verified by computer simulations and analysis, has been known for some time. What was not explained until recently, however, was the reason for differences in responsivity of various film samples. Drs. von Gutfeld and Caswell discovered the answer while investigating conditions under which molybdenum was evaporated onto substrates.

Previously, evaporation had been at a near-zero deposition angle, with molybdenum atoms directed at substantially right angles to the substrate surface. However, by slanting the substrate during the evaporation process, the researchers found deposition angle to be crucial. By using "slanted deposition"

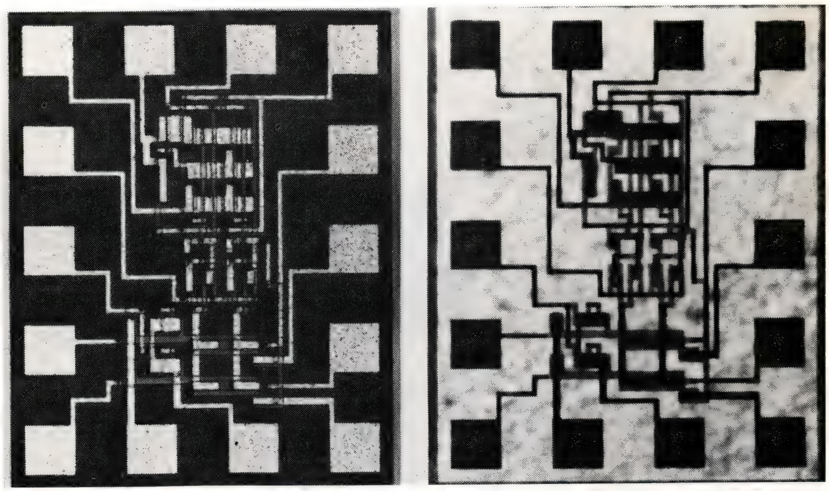
(70° with respect to the perpendicular to the substrate), they increased responsivity from approximately 20 mV for 1 kW incident laser power to about the same voltage for only 1W of incident power—hence the 1000-fold increase in sensitivity.

Precisely this sort of improvement has allowed von Gutfeld and Casell to more clearly detect CW and long-pulse aspects of the laser effect. These had been present, but greatly masked, in earlier low-sensitivity films.

Shown in the photographs are high-magnification electron-microscope views of molybdenum films. Note that slanted deposition results in growth of columns of molybdenum in contrast to the rather featureless surface produced by right-angle deposition. Present data indicates that a columnar-growth surface is especially likely to interact with a number of gasses, such as water and oxygen. Such interaction may account for the heightened sensitivity. This is particularly true if it helps to lock stress into the growing film in such microscopic structures as the boundaries which separate individual grains of metal.

Work is continuing to obtain a more exact model for the thermoelectric phenomenon. Should practical devices result, applications might range from simple laser detectors, to the triggering of various processes through use of laser signals, to possible communication system implementations.—*WP*

ESFI technology adds on-chip decoders and nearly bipolar speeds to MNOS memories



Simultaneous data entry and deletion, just as in the case of core storage, are possible with this ESFI-MNOS memory incorporating substrate terminations connected in parallel. Manufactured in the Siemens Research Laboratory, the experimental IC is seen in incident light (**left**), and in transmitted light (**right**).

Three different, fully decodable experimental MNOS memories using ESFI (Epitaxial Silicon Films on Insulators) technology have been manufactured in the Siemens Research Laboratories. These IC's combine the advantages of nonvolatile information storage with those of CMOS technology. In contrast to bulk silicon components, the process is able to accommodate both memory matrix and decoder on a single chip without requiring insulating wells.

Short access times comparable with those for bipolar memories are essentially achieved by employing an insulator as substrate to reduce parasitic capacitances. The silicon film between the transistors of an MNOS memory can be etched away to prevent interaction between two neighboring memory cells. It is also possible to provide a separate connection to the substrate of each memory transistor and to use it to enter and delete information.

Three versions were built

In the first of the variants, no external connections are provided for memory transistors. Principle of operation corresponds to that in bulk silicon MNOS memories. The decoder itself is manufactured using CMOS technology.

The second variant incorporates series-connected substrate terminations. This allows memory signals to be read in or deleted with voltage pulses of the same polarity. The decoder can be built using single-channel technology, which has the advantage of higher packing density but entails a slight reduction in switching speed.

A 4k, 100 nsec RAM?

In the third variant, substrate terminations are connected in parallel, making it possible to enter and receive data simultaneously in the same manner as with core storage. This means that it is now feasible to build a

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	Driver	2N4427
UHF mobile	Receiver RF amplifier	MM8006
	Receiver L.O.	MM8006
	Multiplier	2N6305, 2N4427, 2N3948
	Driver	2N3948, 2N6256, MRF628
900 MHz mobile	Receiver RF amplifier	2N5031, 2N4957
	Receiver L.O.	2N5031, 2N4957
	Multiplier	2N6304, MRF515
	Driver	MRF816
VHF portable	RF output	2N4427
UHF portable	RF output	2N3948, MRF628
900 MHz portable	RF output	MRF816
VHF aircraft	Driver	2N3866*, 2N3553
UHF military	Receiver RF amplifier	2N5031
	Driver	2N3866*, MRF509
Class D citizen's band	RF output	MRF8004
Proposed Class E citizen's band	Driver	MRF207, MRF225, MRF227
VHF aircraft	Driver	2N3866*, 2N3553*, MRF509
UHF military	Receiver RF amplifier	2N5031
	Driver	2N3866*, MRF509
Sonobuoy	RF output	2N4427, 2N3553*
Radiosonde	Oscillator	MM8009, MRF515
Paging receivers	Oscillator	MM8006
	RF amplifier	2N5031
	Mixer	MM8006

FOR INSTRUMENTATION

Oscilloscopes	Vertical amplifier	PNP 2N4957-59, 2N5829 NPN 2N2857, 2N3839, 2N5031-32, MM8006-7
	Gen'l purpose, low-level circuit	2N2857*, 2N5179, 2N3866*, 2N5109, 2N5160, 2N5583, 2N6304-5
Signal generators/Sweep generators	Oscillators, output amplifier circuits, RF control circuit	2N3866*, 2N5943, 2N5179, 2N6304, 2N5947, MRF511, MRF515
Pulse generators	Pulse amplifier	2N5941-42, 2N3960*, 2N5835-37 MM4049, 2N5583
	Pos/neg pulse amplifier	PNP/NPN complements: 2N5583/2N5943, 2N5031/2N4957 2N3866*/2N5160
Counters	High speed switching interface circuit (I.E. logic)	2N5841-42, 2N5835-37 2N3960*, MM4049, 2N5583

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fast MNOS RAM. A 4096-bit memory of this type is expected to require an active chip area of around 16 mm^2 and to operate with an access time of 100 nsec. Upon entry or deletion of data, voltage pulses lasting about 1 µsec would be produced.

The future for ESFI-MNOS memories looks very bright, since they could be applied to a wide variety of fields. In particular, their low power requirements favor their use in such applications as portable equipment, remote systems, small computers and emergency backup equipment.—*WP*

Winners in EDN's 3rd Annual Creative Design Contest

Last issue (EDN July 20, 1974) featured the contest's grand prize winner as well as three other winning designs. Here, for the record, is a complete list of the top eleven contest entries. These successful designers are to be congratulated, for their designs had to compete against many other fine entries. To all those who entered but did not win, EDN's staff thanks you for your participation. We look forward to seeing your name among the winners in 1975—*RF*

* Robert J. Kerber Eastlake, OH 44094	Digital grandfather clock with tone generator
Jack Regula Conshohocken, PA 19428	FM receiver frequency synthesizer
John E. Bjornholt Scottsdale, AZ 85257	Micropower metal detector
Roger Simister Redwood City, CA 94063	Super sync adds stereo to home movies
Robert S. Scott Wappingers Falls, NY 12590	Home/vacation data center
I. A. Glibbery Chula Vista, CA 92010	Fast response miles/gallon indicator
Richard H. Breinlinger Concord, MA 01742	Automobile burglar alarm/ windshield wiper control
Jeff C. Campbell Houston, TX 77024	Digital clock with BCD output
Richard Ehlinger Southold, NJ 11971	Match-A-LED game
Jack Frost Loveland, CO 80537	Digital tachometer
Joseph Tobin Escondido, CA 92025	Keyless alarm lock

* *Grand Prize Winner*

Liquid bubbles could be the key to low-cost graphic displays

Techniques for forming and moving liquid magnetic bubbles were conceived at IBM's Thomas J. Watson Research Center by Lubomyr T. Romankiw and David A. Thompson, and implemented by Marco G. Slusarczuk, an MIT student who worked at IBM last summer. In a paper presented May 17 at the 1974 INTERMAG Conference in Toronto, they noted that because the liquid bubbles are easily visible without any optical aids, they may be useful as the basic elements of a low-cost graphic display device.

The process can be briefly described as follows: Sandwiched between two glass plates, liquid magnetic bubbles (about the size of the period in this sentence) stream through a transparent fluid. As an externally applied magnetic field rotates, continually reversing the polarities at the tips of the "T" bars,

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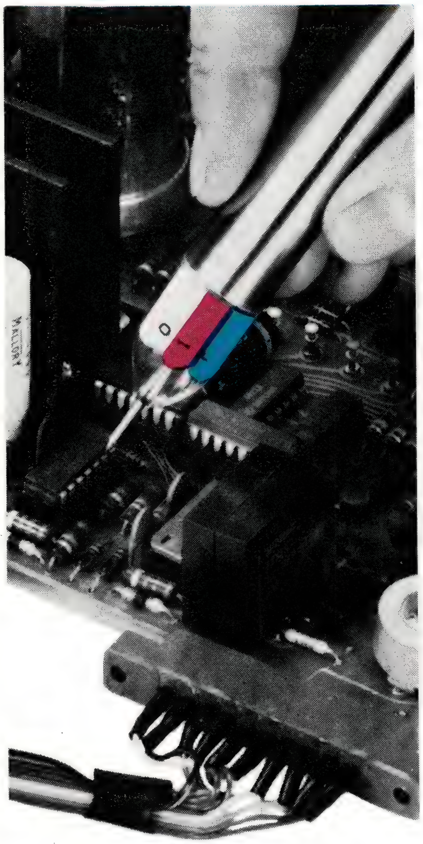

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Logic probes are also available for MOS, HTL, RTL and discrete logic. Prices from $6995 to $9995. Send for free literature. For a 30 day free trial probe or special information, telephone Tom Barth, General Manager, Kurz-Kasch Electronics, 2876 Culver Ave., Dayton, Ohio 45429, Telephone: (513) 296-0330

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ELECTRONICS DIVISION

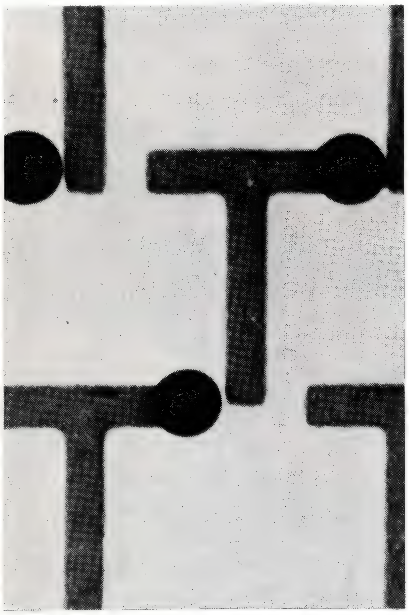
Circle No. 24

the bubbles are pulled along the tops of the bars.

Bubbles are formed when a mass of magnetic liquid—a colloidal suspension of microscopically-small magnetic particles—is broken up into spherical droplets by a constant magnetic field. Such field is applied perpendicular to the plane of bubble motion.

A bubble domain analog

The "T"-bar circuit pattern is a 20-times-size replica of a circuit previously designed to direct the motion of so-called "bubble domains" in solid magnetic materials. Experiments have shown that liquid bubble behavior in this circuit is, in several ways, a large-scale analog of bubble domain behavior. Bubble domains are actually tiny cylinders, magnetized in a direction opposite to that of the surrounding material. They are currently of considerable interest in computer research because of their potential application in high-density data storage and switching devices.—*WP*



Tiny liquid bubbles are pulled along the tops of the bars as an externally applied magnetic field rotates. Techniques for forming and moving the easily visible bubbles were conceived and implemented at IBM.

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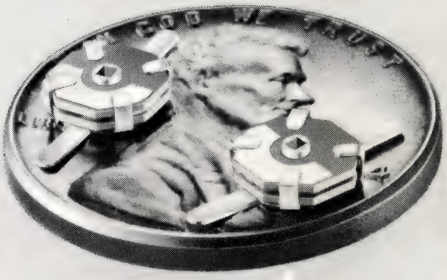

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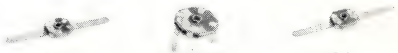

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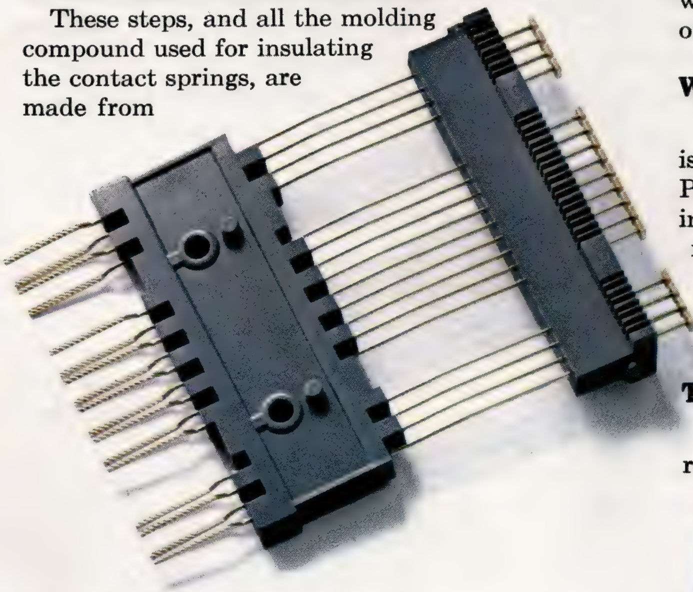
Our Class W wire-spring relay is different. In fact, there's nothing like it in the entire industry. Where else can you find a relay with 51 poles for transferring circuits and a mechanical life of more than a billion operations! That's about two and a half times the life of the best conventional relay around.

Another nice thing about our Class W is that it takes up a lot less space and costs less than using a bunch of other relays. That's because we build our Class W relay with one, two or three levels of contact assemblies, with 17 form C combinations per level. By the way, they're available with gold contacts for low-level switching.

Making it tough on creepage.

All those staggered steps you see on the side were put in to raise the breakdown voltage between terminals. These molded steps add extra creepage distance between the terminals. This really counts for high voltage testing, or when using our Class W in unfavorable ambient conditions.

These steps, and all the molding compound used for insulating the contact springs, are made from diallyl phthalate. (They call it DAP for short.) It has great insulating properties and it wears like iron. Even if the humidity is high, you have excellent protection.



Redundancy—two springs are better than one.

Each of our long wire-spring contacts has an independent twin with the same function. One tiny particle of dust could prevent contact on other relays. Not with our Class W. You can be sure one of the twins will function. That's back-up reliability.

The twin contacts are twisted together at the terminal end. Then we give them a spanking (you might call it swedging) to provide solderless wrap.

We're for independence.

Our springs are longer, because the longer the spring, the more independent they get. And the better contact they make. Don't forget, the wire-spring relay is the most reliable way to get a permissive make or break contact. You can rely on it.

The middle contact springs have to be stationary. To make sure they stay that way forever, we actually mold them between two thick pieces of DAP on both ends. Just try to move one.

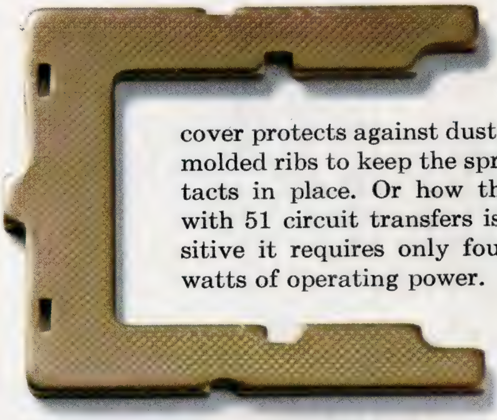
When we say flat, it's flat.

Each frame, banged out by a gigantic machine is extra thick and extra flat. Then they're planished. Planishing is another step we go through in forming the frame to add strength and stability by relieving surface strain.

We've made our spring-loaded pile-up clamp extra thick, too. Once it's tightened down, the whole pile-up is nice and tight, and stays tight.

There's more.

We could tell you a lot more about our Class W relays. Like how the tough high-temp molded cover protects against dust and has molded ribs to keep the spring contacts in place. Or how this relay with 51 circuit transfers is so sensitive it requires only four to six watts of operating power.



But why don't you let us prove how much reliability we put into our Class W? We'll be waiting to hear from you. Government Industrial Sales Division, GTE Automatic Electric, Northlake, Illinois 60164.

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Hybrid circuits: born in space, growing up on earth

Hybrid circuit technology is no longer limited to space electronics. Hybrids offer a viable solution to today's commercial design problems.

Carl Kramer, Robin Heller and Hollis Hardy, Hybrid Systems Corp.

Until very recently, hybrid circuits were confined, almost exclusively, to aerospace, military and outer space applications. The design constraints common to these fields forced hybrid development along a straight and narrow path. More and more components squeezed into smaller and smaller packages. Save space; save power; go for broke in reliability; these were the slogans heard by hybrid designers.

This "money is no object" design philosophy adversely labelled the hybrid and prevented its expansion into other fields. Too expensive—only suited for exotic applications—not right for commercial electronics: these justly deserved labels served to keep the hybrid in space.

Today, the hybrid still offers the only viable solution for many space applications, both military and commercial. But if you haven't looked at hybrids for awhile, you'd better look again. Hybrids have gone commercial, and have done it in a big way. And if your application is properly chosen, you can do more than save space. Hybrids will give you better circuit performance than discretes, and can save you money in the bargain.

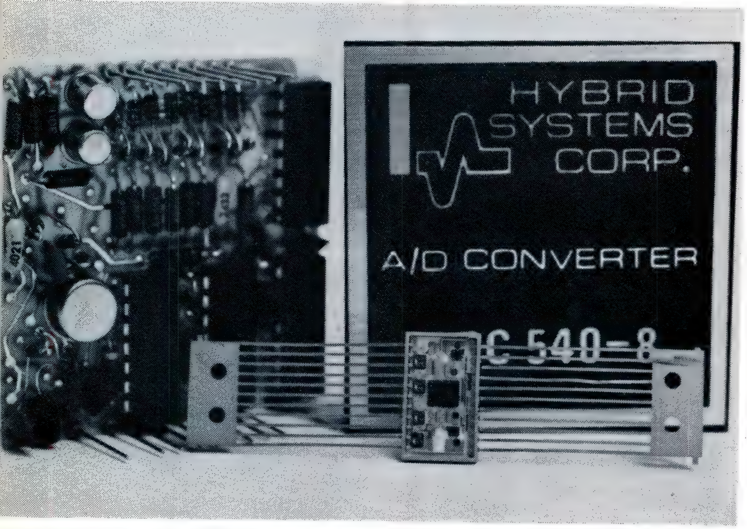


Fig. 1—The hybrid's size advantage is obvious. While not identical, both circuits have the same degree of complexity.

Hybrids come down from space

In the early days, most companies in the hybrid business were a division of an aerospace or military company. Any outside business solicited was strictly on a fill-in basis. Because familiarity breeds success, the business solicited was aerospace in nature, where the "money is no object" slogan prevailed.

Automotive, industrial and medical electronics have brought the dollar factor back into hybrids, and new blood with it. Commercial and industrial companies serving these markets have branched into hybrids and reoriented the hybrid business to lower their costs. Why is it possible, all of a sudden, to reduce costs? There's no black magic involved.

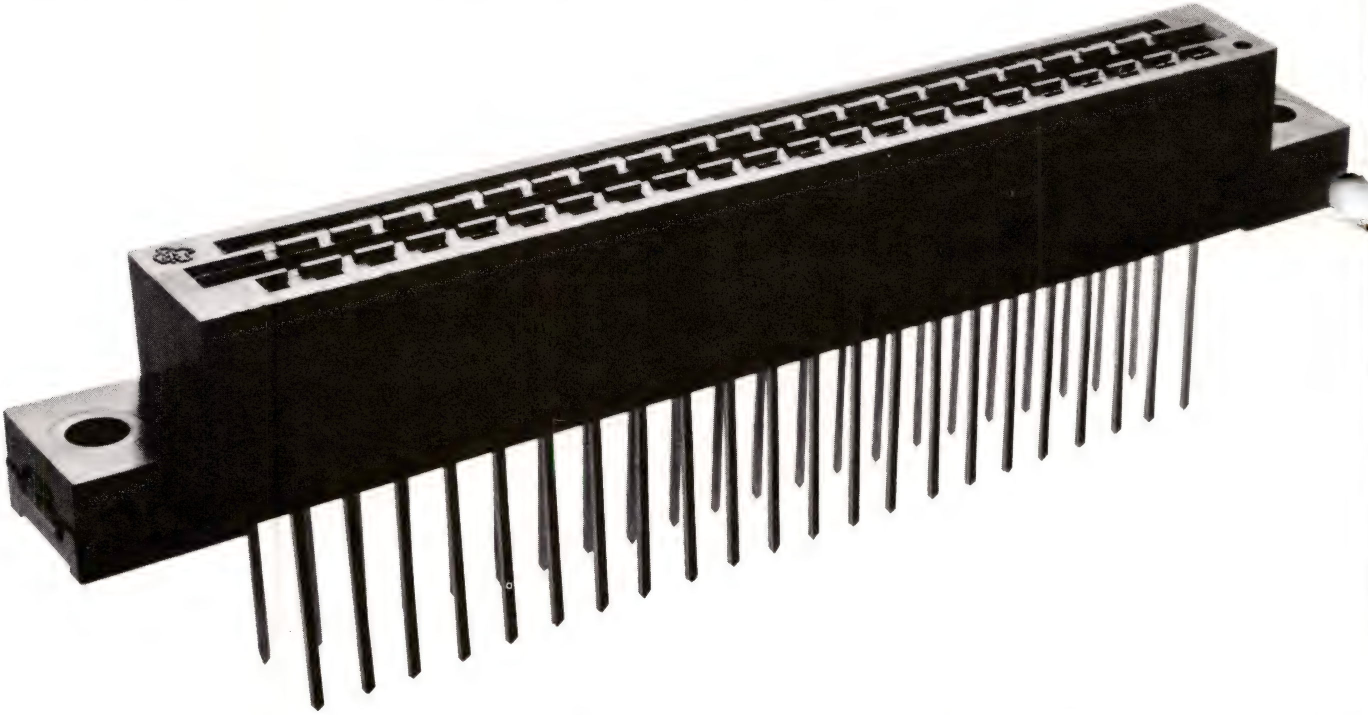
Technological advances have made their contribution. New process equipment has made hybrids less expensive to build. The advent of epoxy die-mounting makes limited in-process repair more convenient. The improved yields that result thus lower costs.

Initially, semiconductor houses considered hybrids a threat and performed only minimal screening of active chips. As the availability of fully screened chips increased, hybrid houses no longer had to assume the entire costs of chip yield. This by itself produced significant price drops.

TI built a new edgeboard connector by destroying some old connector myths.

And now you can forget about connector intermittencies.

The connector that destroyed the myths.



Our new edgeboard connector isn't built the way old edgeboard connectors were built. It's built better. Better because it conforms to the kind of use connectors really get. Not the kind set down in military specs. Specs you don't need. But pay for.

TI's new edgeboard connector is based on a whole new materials system. Materials that make sense in the cost-conscious commercial world. Which brings us to the first myth.

Myth Number One: To get a good contact, it must be plated with gold.

We don't think so. For one thing, plating is porous, thus vulnerable to abrasion. And intermittencies. Plating is also wasteful. You only need gold at the exact spot of contact. Welded gold dots help. But they're damage prone.

Our gold contact, on the other hand, has a metallurgically bonded stripe of non-porous gold, just at the point you need it. No waste. And since it's metallurgically inlaid into the contact, it won't come loose. So forget intermittencies.

Myth Number Two: The spring material must be phosphor bronze.

Not really. We chose Copper Alloy 725 (9% nickel, 2% tin, 89% copper). It has the spring and conductivity of phosphor bronze. But, surprisingly, superior corrosion resistance. And better solderability.

Myth Number Three: The connector body should have a maximum operating temperature of 200°C.

Some like it hot. But we chose a 30% glass filled nylon material for our body. True, a diallyl phthalate body has somewhat better absorption characteristics than ours at higher temperatures. But we felt a mean operating temperature of 125°C was more than adequate for non-military use. And since glass performs equally with diallyl phthalate in terms of insulation, flame and corrosion resistance, we chose it. And one other reason. It costs way less than diallyl phthalate.

Finally, Myth Number Four: Connectors should be custom designed.

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TI's new edgeboard connector, the myth destroyer. It's a whole new way of looking at connectors. Look for yourself.
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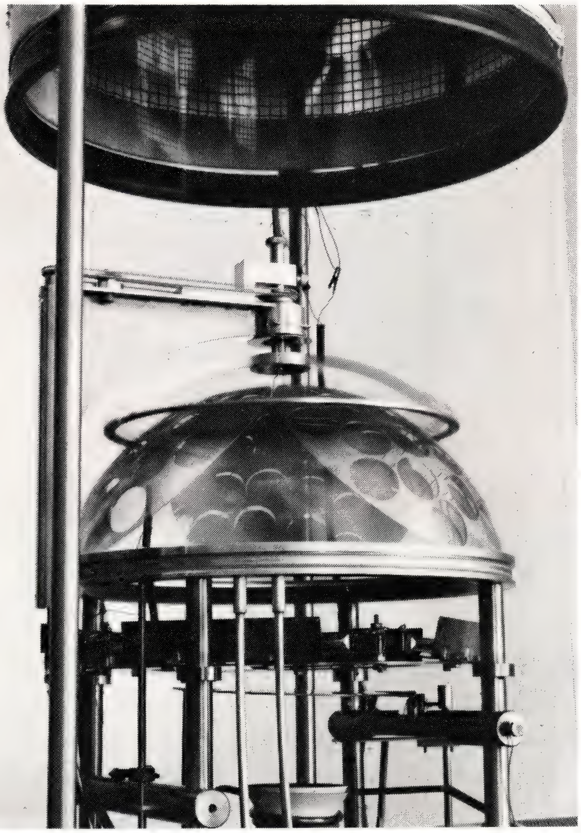

Fig. 2—Tri-planetary deposition equipment provides the vacuum for thin-film evaporation process.

Probably the biggest cost-reducing factor is the market itself. Hybrid is essentially a packaging technology. It is also a volume technology. As markets for high-volume, less complex circuits appear, costs come down. It also has the effect of creating a broader standard product base. One only has to look at the early development cycle of linear IC's. With a limited standard product base, linear lagged behind digital, where high volumes of gates and flip-flops could be cranked out. So it was with hybrids. Amplifiers, oscillators, filters and data converters have now become standard products and down come the prices.

We should say a word here about the standard vs. custom delineation. In hybrids, custom does not necessarily mean small-lot, special circuits. For any designer who doesn't have the in-house facilities, any hybrid is a custom (unless it's on a shelf somewhere). So don't dismiss hybrids solely because your design is not part of a vendor's standard product base. Take a good hard look at the advantages hybrids have to offer before you dismiss them.

Good things come in small packages

The most obvious advantages of the hybrid is its significant size reduction, when compared to a discrete (**Fig. 1**). Let's look at some of the basic elements that lead to this saving.

Consider the active components first. By mounting all IC's, transistors and diodes in chip form, thereby eliminating all TO cans and DIP packages, a substantial saving is realized. From the cost standpoint there are limitations to the chip concept. As the number of chips increases, the likelihood of a chip going bad during fabrication of the hybrid increases. Although epoxy mounting of these die allows for some repair, it is a cost-increasing procedure. As the number of chips increases, the wire interconnections become complex. Space needed for each chip increases exponentially to assure that there is sufficient room for interconnections. Hybrids with more than 10 active chips could negate the hybrid's size and cost advantages.

Resistors are the area where hybrids achieve the most significant saving, in both space and cost. Hybrids and resistors go hand-in-hand; and the more resistors, the greater the savings. When initial resistor tolerance is not critical, thick-film techniques can be used to deposit the resistors directly on the substrate. Thick-film processes are inexpensive and can be used to put large numbers of resistors into a fraction of the space required in discrete designs.

Thin-film technology consists of evaporating in a vacuum (**Fig. 2**) a film of resistive material (usually nickel chromium) on a substrate. By etching a pattern on the film, a resistor (or resistor array) is created. Initial resistor tolerance is much tighter with thin-film techniques. Laser trimming allows accuracies of 0.01%, with tracking tempco to 1 or 2 ppm/°C, to be realized.

Thin-film deposition is particularly well suited for resistor arrays. Resistor conformity and temperature tracking are excellent, since each resis-

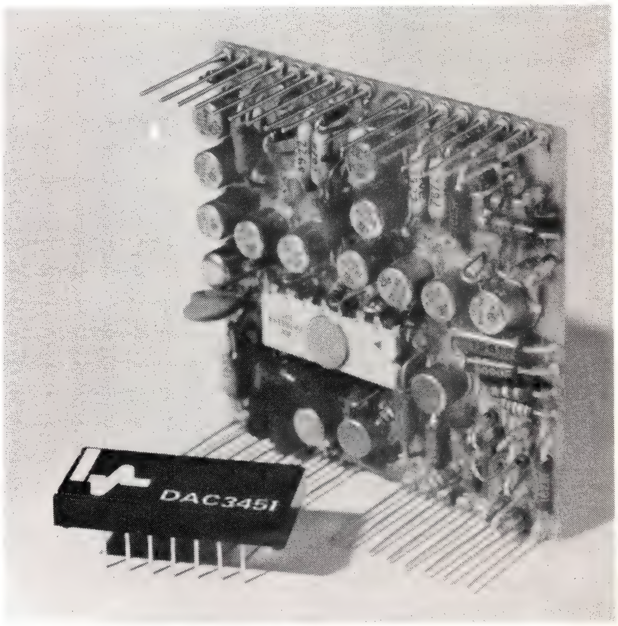

Fig. 3—When it comes to temperature, it's easy to see the thermal-layout problems in discrete technology.

tor on a chip is virtually identical to each other. Moreover, the cost of a resistor array is not significantly greater than the cost of a single resistor. Up to 20 precision resistors can be deposited on a single chip. Thus, when many precision resistors are in a circuit, the hybrid may be less expensive and smaller than discretes, with improved accuracy and performance.

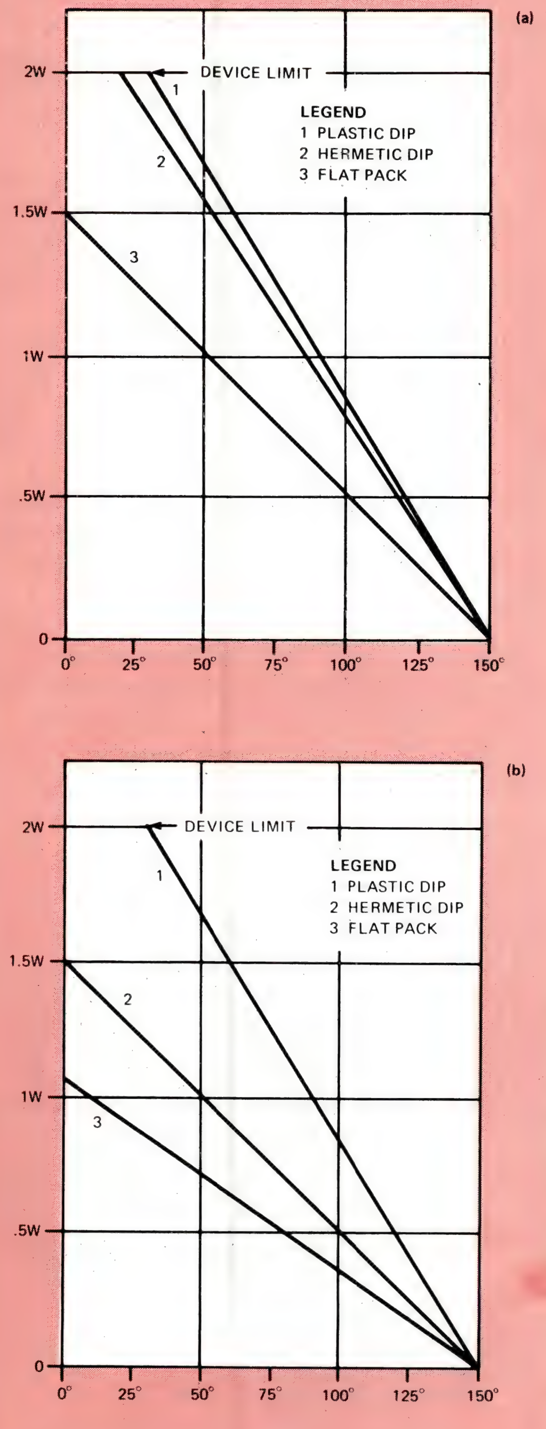

Fig. 4—Package thermal ratings, shown in (**a**), can be greatly improved through use of winged heat sink (**b**).

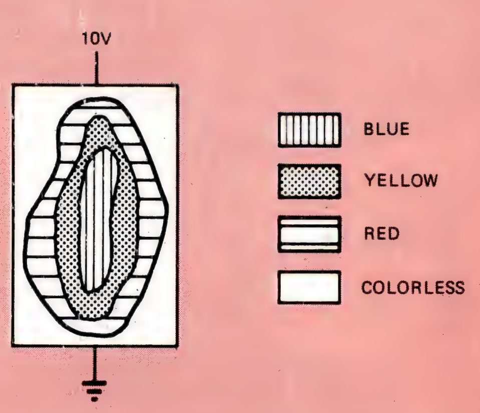

Fig. 5—Temperature distribution on operating resistor is graphically displayed through use of liquid crystals.

It's not that simple a choice

Not every design can be economically fabricated as a hybrid, or any other technology for that matter. Certain types of circuits are made to order for hybrids. Precision circuits, for example, are naturals. Combining the natural accuracy and size advantage of thin-film resistors with monolithic quad current-switches, the D/A converter is a prime example of a hybrid saving (**Fig. 3**). The stability (1 ppm/°C vs. 30 ppm/°C for a discrete) and size (1.0×0.3×0.2-in. vs. 2×2×0.4-in. for a discrete) of this converter simply could not be achieved in any other way. The most significant point is that the costs are comparable.

Why are hybrids more accurate? Functional trimming is why. With the circuit fully powered, resistors are trimmed to produce the output response dictated by input conditions, rather than to a specific resistor value. In monolithic and discrete, what you "build" is what you get; in hybrids, what you "want" is what you get. But it's not all gravy. Design philosophy must change to be compatible with functional trimming.

Your design must no longer have components tightly specified, instead you are going to functionally trim for your desired output. However, your circuit must be able to function in the pretrimmed condition or the ball game's over. With the close initial tolerance of thin films, this is not a major problem. With thick films, the resistor's initial value could be such as to put you out of business.

Also your design must be such that specific components can be trimmed to produce predictable output excursions. Circuits with large capacitor values do not lend themselves to practical hybridization. (It's not that they can't be made; they just will use up too much real estate.) What are we leading up to? Early contact with your vendor.

A direct one-for-one translation of your discrete design into hybrid will, in many cases, not be cost effective. Good hybrid houses are staffed with circuit designers as well as process and packaging engineers. The circuit people may be able to simplify your design and make it practical for hybridizing. Make sure you have tested your design to the degree where you can point out critical components that may require selection or special testing. It will be cheaper to find this out early; not after a long run of production circuits.

Now that we've discussed various aspects of hybrid circuits in a general manner, let's look more closely at one rarely discussed area—the effects of power dissipation on reliability and stability of thin-film resistors.

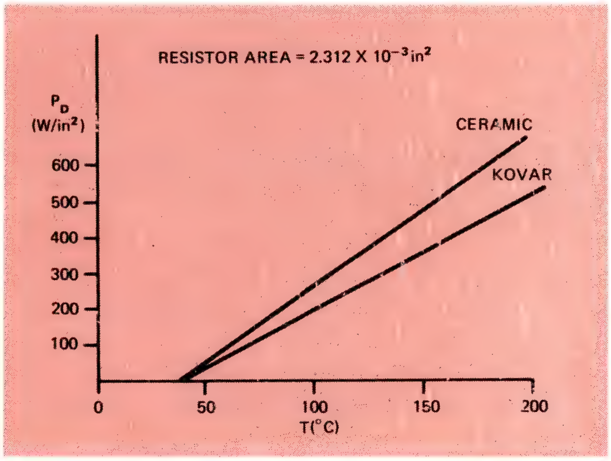

Fig. 6—Dissipation vs. temperature for ceramic and Kovar-bottomed, 14-pin 1/4×3/8-in. flat packs. Same resistor network is in each package.

High-temp. performance of thin-films

The maximum power-dissipating capacity of thin-film nichrome resistors has been an often asked question since the advent of nichrome resistor networks. With the ever increasing utilization of thin-film networks, a thorough knowledge of the resistors' capabilities must be obtained in order to gain a complete understanding of their ultimate reliability.

A power-dissipation figure formerly used for thin-film resistors was 15W/in.^{2}. However, this estimate falls far below recent experimental results, which show that power dissipation varies from one fabrication technique to another. This occurs because film structure varies as a function of the deposition method.

Deposition methods range from sputtering by either RF glow-discharge, dc diode or dc triode, to chemical deposition, RF-heated vacuum evaporation and electron-beam evaporation.

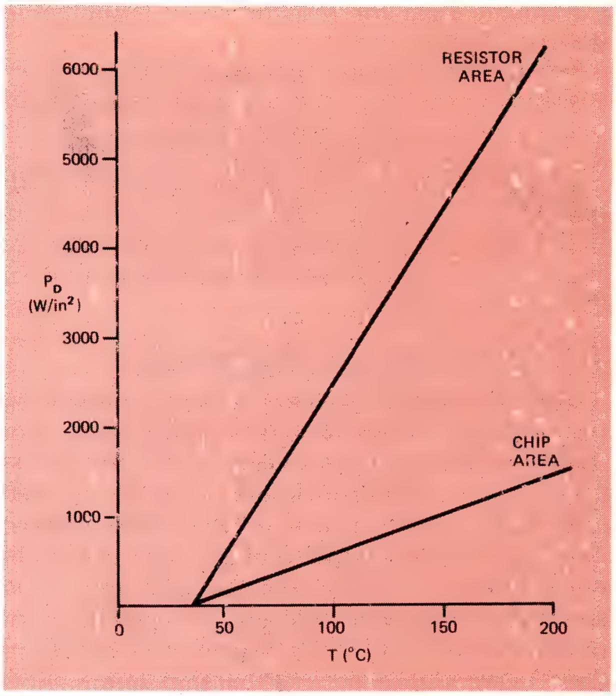

Fig. 7—Dissipation vs. temperature on chip using resistor area of 1.97×10^{-4} in.^{2} and chip area of 9×10^{-4} in.^{2}; chip size, package size and composition, and resistor value held constant.

Data presented in this article was obtained using resistor samples of 65% Cr-35% Ni composition. The samples were produced via the RF-heated vacuum evaporation process. While the possibility exists that this data may only apply to films fabricated by this process, there are other variables which determine the maximum power any chip will dissipate. Among them are:

- Package size and composition
- Chip size vs. resistor density on the chip
- Resistor value
- Maximum temperature the chip's surface will withstand before intermetallic corrosion attacks the gold wire-bond/aluminum contact-pad interface. Above 180°C, "purple plague," for example, may begin forming at the gold-aluminum interface. This problem may be circumvented by use of aluminum ultrasonic bonding.

To eliminate several of the previously mentioned variables, the following conditions were imposed during tests. Package size was maintained constant, as studies on their dissipation abilities have already been performed. (**Ref. 1** provides data which correlates a unit's ability to dissipate power to the package form used.) For the purposes of this article, 14-pin 1/4×3/8 Kovar and ceramic-bottomed flat packs were utilized. Comparisons of flat packs to plastic DIP and hermetic DIP, with and without attached winged heat sinks, are shown in **Fig. 4**. The graphs provide a sound basis from which one can extrapolate data for resistor chips mounted in these packages.

In order to avoid operation above 180°C, temperature is used as a constant, with voltage and current values recorded at each temperature. Various methods exist to study power dissipation when temperature is held constant. Since the final choice will require some tradeoffs, a discussion of the advantages and disadvantages of each method is in order.

The choice may be crystal clear

Several methods are available for measuring the surface temperature on resistor films: infrared radiometers, indicating paints and phosphors, and cholestric liquid crystals. Infrared radiometers are popular because no surface contact is required, and small temperature gradients across a surface can be observed. The sensitivity of radiometers permits tracking of rapid changes in surface temperature of the unit. Their major shortcoming is that the equipment is large and expensive. Most infrared measurements are performed by monitoring a single point. Scanning systems can be devised but they are often difficult to use and are extremely expensive. So unless a great investment in both time and energy is warranted, this method is a poor choice.

Temperature paints are irreversible in the temperature range. This creates a problem when zeroing in on a specific temperature. In addition, paints and phosphors lack proper definition to respond to small, rapid temperature variations.

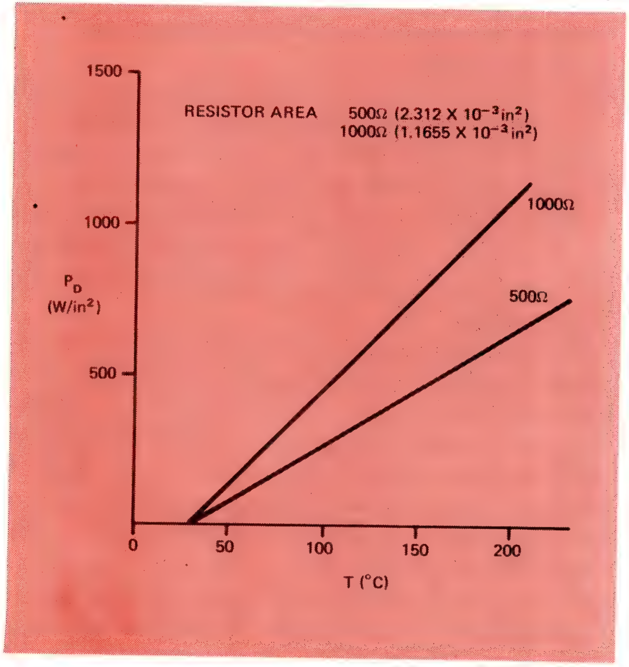

Fig. 8—Dissipation vs. temperature as resistor value and area are varied. Chip size, package size and composition are held constant.

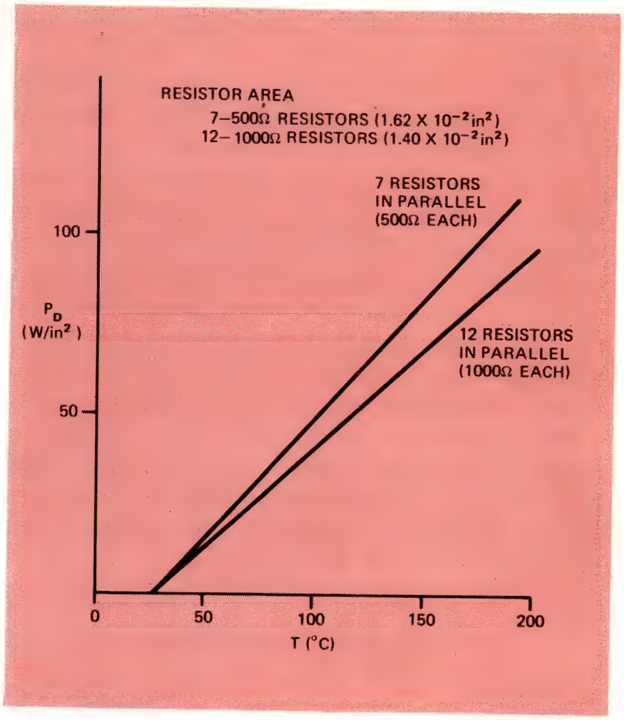

Fig. 9—Dissipation vs. temperature for varied number of resistors run in parallel. Chip area, package size and composition are constant.

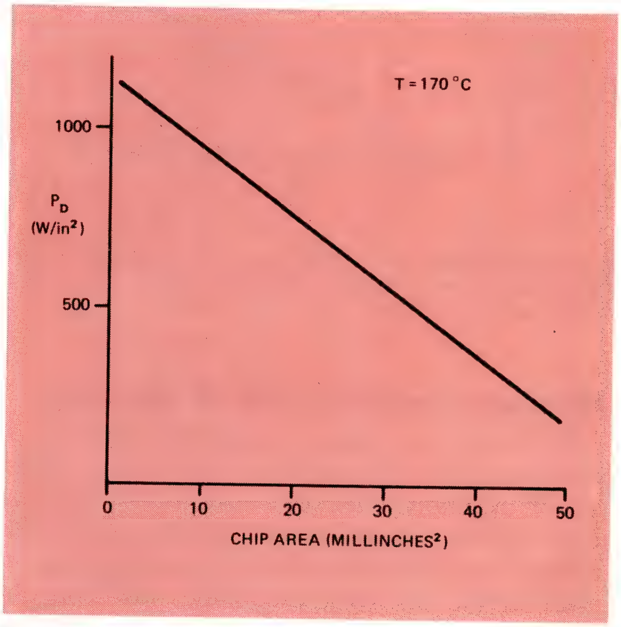

Fig. 10—Dissipation vs. chip area; temperature, package size and composition held constant.

Liquid crystals, on the other hand, are a group of cholesterol esters which, in liquid state, exhibit optical properties typically associated with solids. The bulk material is inexpensive, about $25 for 50 cm^3. (One cubic centimeter of solution covers 1000 cm^2.) Liquid crystals are reversible over each temperature range (operating ranges cover −20 to +350°C), and are only 10 to 25 microns thick. This low thermal mass allows for rapid thermal tracking.

Also, liquid crystals provide a graphic display of temperature gradients across a thin-film resistor network as well as diffusion of heat into the package. If a dark background is provided, the reflected light can be observed visually as the temperature changes on the unit's surface (**Fig. 5**). For ease of application and precision of temperature measurement over large areas, this method is the best.

Measurement variables must be reduced

In order to determine the optimum design power rating, various questions must be explored. The primary question under investigation is the maximum power a chip can tolerate and still be capable of functioning as intended. The scope of the preceeding problem, being too broad for a general answer, can be broken down into reasonable segments. The primary task is to ascertain how power dissipation varies as a function of package composition, chip area and resistor density on a chip. Once these characteristics are determined, other questions need answers. For example: Is the power per unit resistor area or per chip area? How does power dissipation vary across the chip?

Experimentally, the temperature on the chip's surface was measured using liquid crystals. At predetermined temperatures (75°C, 135°C, 170°C), the crystals' layer orientations rotate to produce a spectrum of colors. Voltage and current are measured for each unit at each temperature. The area of each chip is known, so power/unit area can be found. (Note: the liquid crystals should be calibrated for each temperature solution. Once calibrated, a specific solution will remain constant in temperature.)

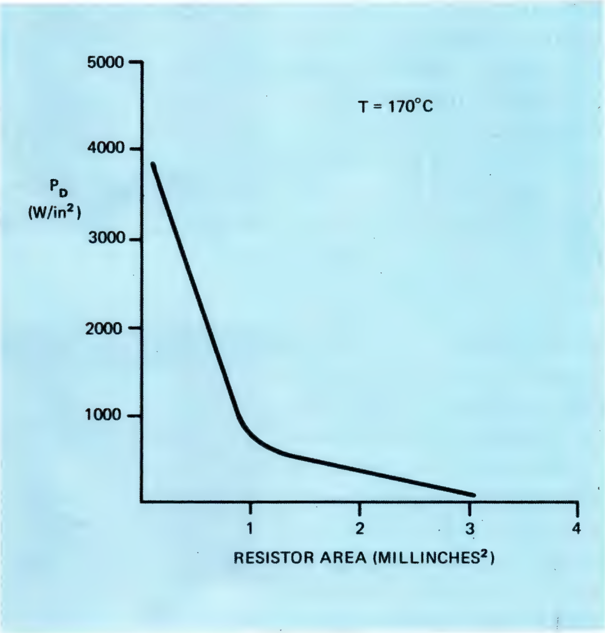

Fig. 11—Dissipation vs. resistor area; temperature, package size and composition held constant.

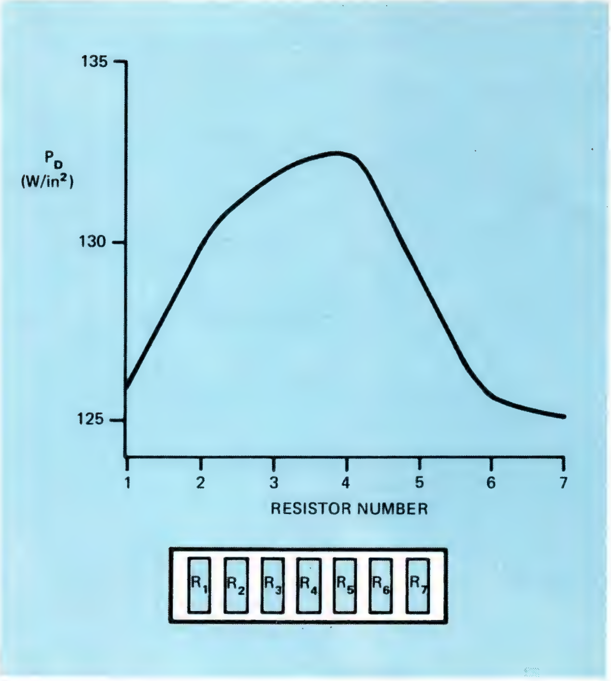

Fig. 12—Dissipation vs. resistor location across chip; temperature held constant.

The evidence is conclusive

This study proves that power dissipation is really per unit chip rather than per unit resistor. This is most dramatically characterized in **Fig. 7**. The resistor is so small in area that the temperature gradient on it can barely be seen.

Using the other graphs (**Figs. 6 to 12**), it is possible to determine the power-dissipating capacity of a chip by: relative chip size to package size, substrate on which chip is mounted, resistor value and resistor area. The following two relationships can be formulated from the graphs:

$$\left.\begin{array}{l}\text{Power rating (W/in.}^2\text{)}\\ \text{of resistors powered}\\ \text{in parallel}\end{array}\right\} = \left\{\begin{array}{l}\dfrac{\text{Power rating for one resistor powered alone}}{\text{Number of resistors connected in parallel}}\end{array}\right.$$

And,

$$\frac{\text{Area R(large)}}{\text{Area R(small)}} = \frac{\text{Power rating R(small)}}{\text{Power rating R(large)}}$$

Both relationships are logical and easily derived. The important fact is that experimental data agrees with basic truisms. ☐

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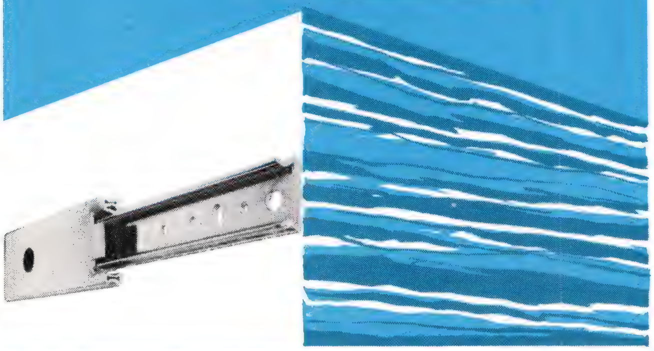

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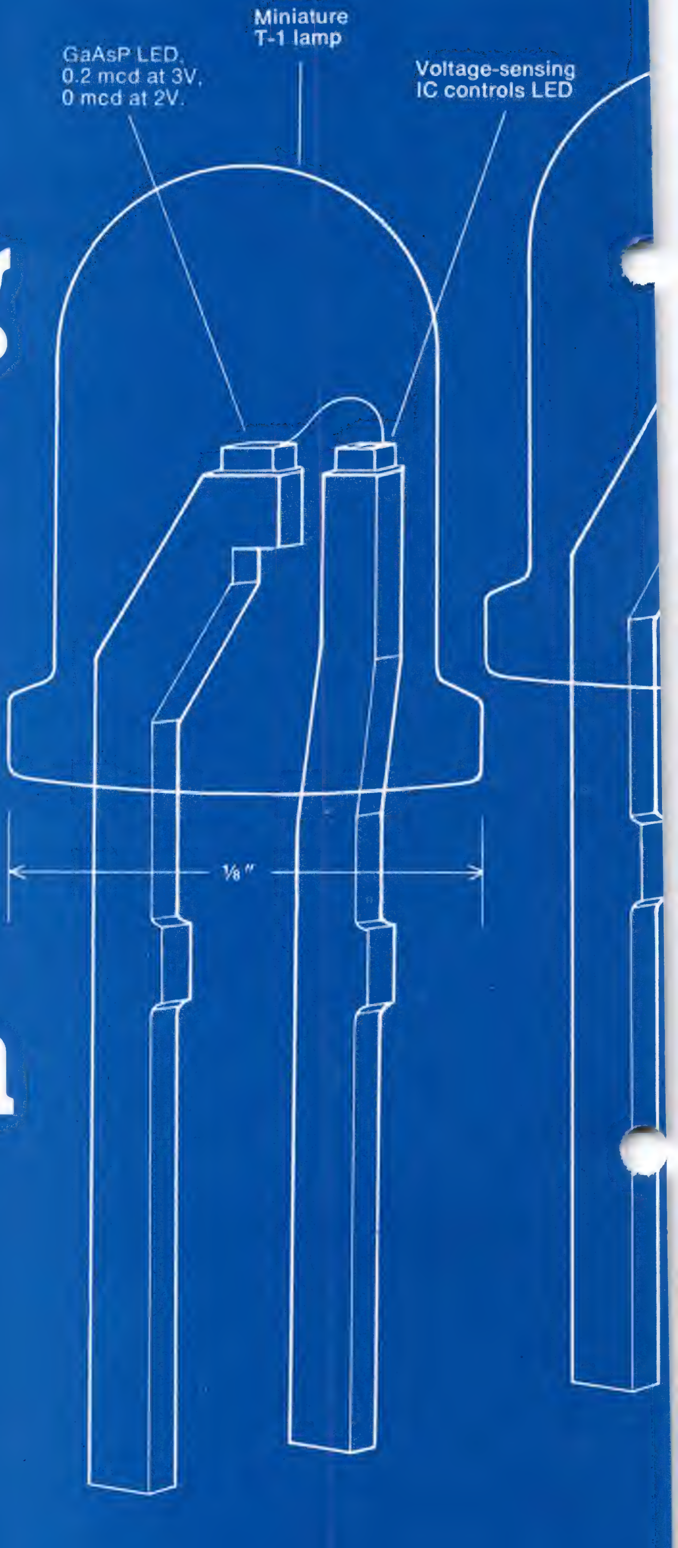

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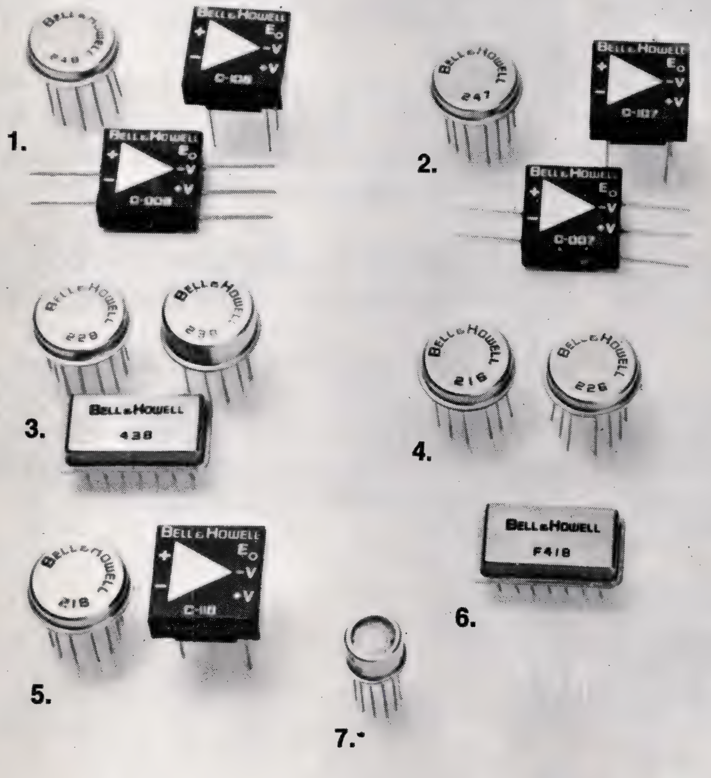

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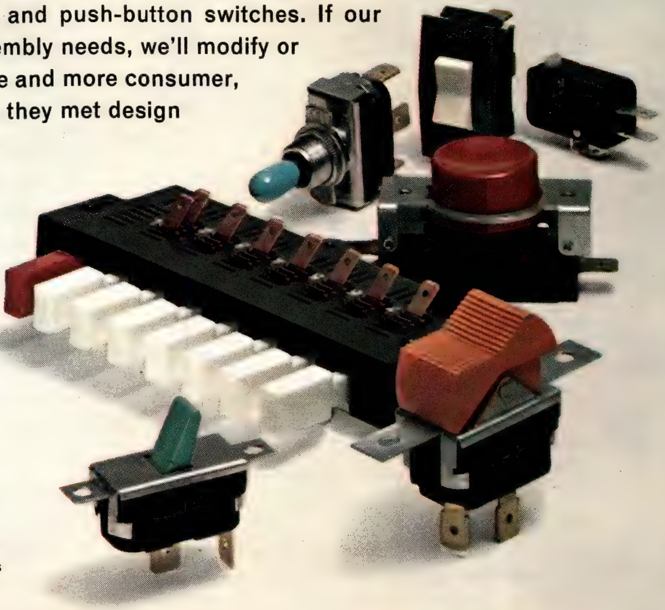


How to get the most out of high-power rectifiers and SCR's

Are your power-semiconductor designs sub-optimized? They won't be if you consider all the factors detailed here.

Woody Savage, Westinghouse Electric Corp.

Can a product produce too many benefits? Perhaps this is the case with modern high-power rectifiers and SCR's. They can now be found in almost every application imaginable. Most designers converted their systems and circuits to solid state because these devices offered many advantages, including lower initial costs, lower maintenance costs, longer service life, higher efficiency and increased reliability. The trouble is that these combined savings were often so great that little consideration was given to optimizing rectifier or SCR performance.

In this regard, another factor was at work as well. Historically, power semiconductor prices have declined with time. Therefore, designers typically have overspecified devices, depending upon price declines to help them achieve cost-reduction objectives. Unfortunately, due to the basic nature of power rectifiers and SCR's, the pattern of continual price reductions is bottoming out. Further device price decreases resulting from new technological developments and/or increased sales volume can be expected to be more than offset by higher costs of raw materials (including silicon, moly and copper), and by higher labor costs. Moreover, such rising costs aren't limited to component manufacturers. Equipment makers also face cost spirals.

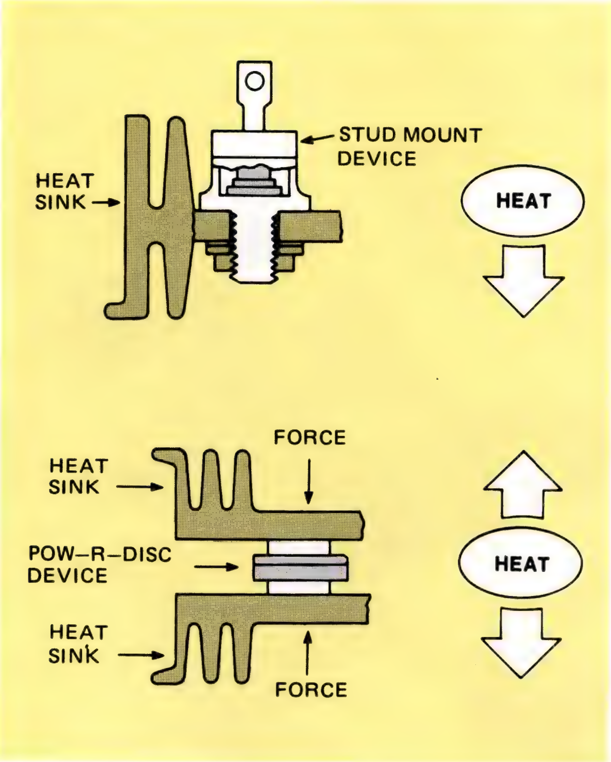


Fig. 1—Double heat flow path of disc-type rectifier or SCR is more efficient than single flow path for conventional stud-mount device.

Combine these factors with the increasing need for energy conservation and you can easily see why power rectifier and SCR circuits are under close scrutiny. Are they optimally efficient? Can they be improved? Do they take advantage of the new package designs and better assembly techniques now available? True, state-of-the-art components offer substantial increases in current output, efficiency and reliability, as well as somewhat lower overall costs. Nevertheless, the pressure is on to use them effectively.

Treat both as a single unit

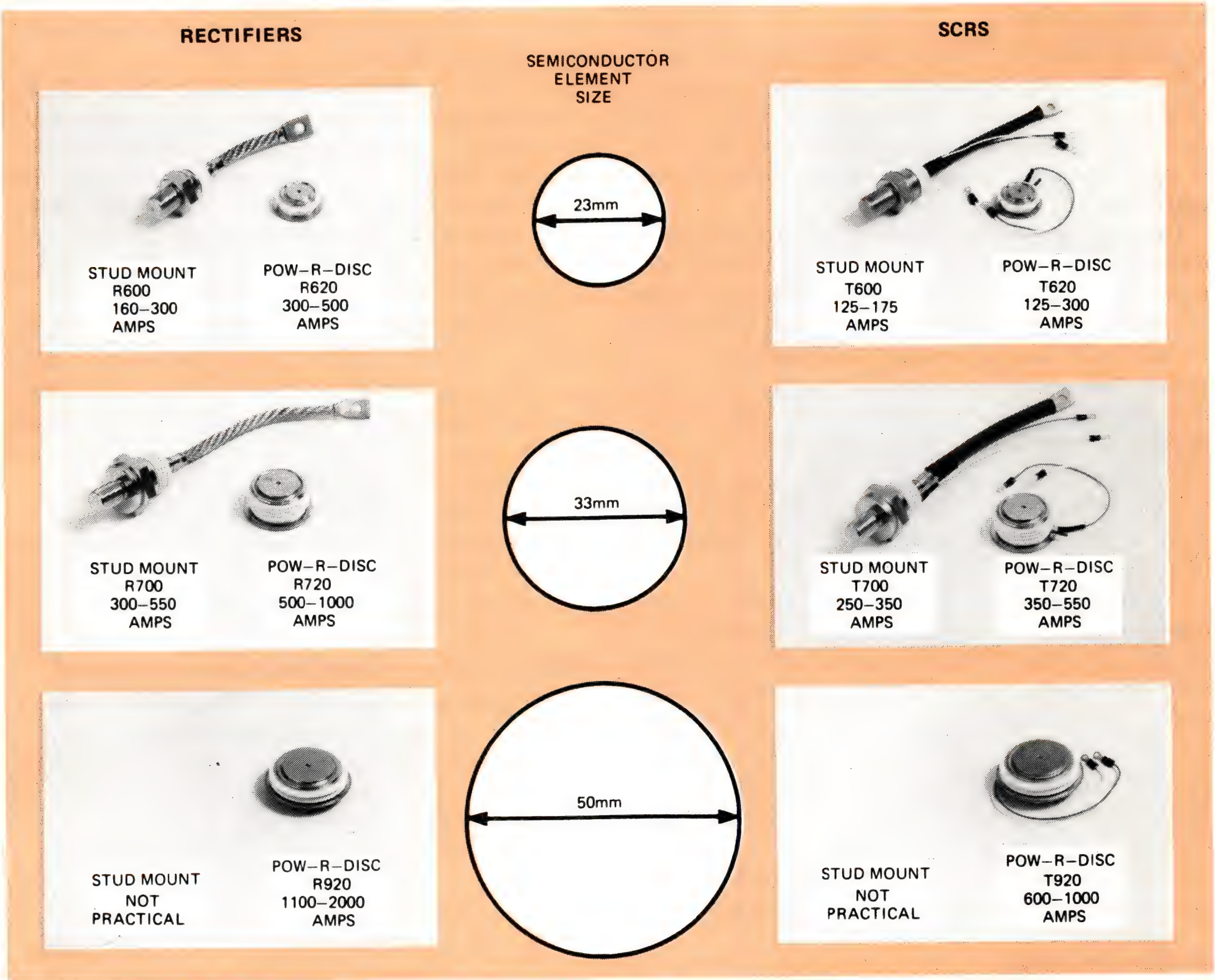
Before we can help you get the most performance out of your power semiconductors, you must at least have made several basic decisions. You must have determined the type of devices needed (rectifiers and/or SCR's), ascertained the optimum circuit configuration and calculated the required current and voltage ratings.

With this knowledge as a base, we can proceed to select the best semiconductor for the job. The key to this process is to treat the semiconductor and heat exchanger as a single unit, then follow these three steps:

(1) make a package selection;
(2) choose the type of cooling or heat exchanger;
(3) make a "build or buy" decision.

Package: stud-mount or disc?

The first step is to select the best semiconductor package for the job. We want the one that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SCRS
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STUD MOUNT R600 160–300 AMPS
POW–R–DISC R620 300–500 AMPS
STUD MOUNT T600 125–175 AMPS
POW–R–DISC T620 125–300 AMPS
33mm
STUD MOUNT R700 300–550 AMPS
POW–R–DISC R720 500–1000 AMPS
STUD MOUNT T700 250–350 AMPS
POW–R–DISC T720 350–550 AMPS
50mm
STUD MOUNT NOT PRACTICAL
POW–R–DISC R920 1100–2000 AMPS
STUD MOUNT NOT PRACTICAL
POW–R–DISC T920 600–1000 AMPS

Fig. 2—Higher output current ratings are obtained from disc rectifiers and SCR's when compared to stud-mount devices of an equivalent element size.

will provide the most output current and/or the greatest safety factor (for high reliability applications) at the least cost.

Stud-mount devices were the first types sold. They were easy to mount and could be installed by almost any manufacturer. This package design was suitable for many years, since the current rating/device never exceeded 200 to 300A. Later, as the demand for higher current devices evolved, the disc package design was developed. (Trade names for disc-type power semiconductors include "Pow-R-Disc," "Hockey Puck" and "Press Pak.")

Unlike the stud-mount device, where all of the heat is dissipated through the stud base of the package to a single heat sink, the disc-packaged device dissipates heat through both upper and lower pole faces to two separate heat sinks (**Fig.1**). Thus, a disc rectifier or SCR with double-sided cooling offers higher output current ratings than conventional stud-mount rectifiers or SCR's of equivalent element sizes (**Fig. 2**). In fact, not only does a disc unit offer up to 80% more current rating, but it generally costs less too, so it's a better buy.

Limiting factor is heat exchanger

A semiconductor can be no better than its heat exchanger! This statement is especially true when comparing larger device types. Optimum performance and lowest assembly cost is achieved when the system is designed for the most effective cooling method. As such, we will discuss in detail air vs. water cooling.

Air cooling

The ability of a heat sink to transfer heat to the surrounding ambient air depends upon several parameters, including material, surface area, volume, natural convection or forced air, fin spacing, finish and type of enclosure. The goal is to optimize all of these parameters in choosing the appropriate sink.

Copper heat sinks have long been recognized as being the most efficient in terms of heat transfer/unit volume, while aluminum heat sinks offer the best performance/unit cost. One might conclude from this that a copper heat sink must be used if an optimum heat transfer rating is required. This is not necessarily the case. Much development work has been done in recent years in optimizing the fin pattern design for aluminum extrusion.

Fig. 3 shows two popular aluminum extrusion designs. A comparison was made between this type of heat sink and a copper fin design where both heat exchangers were designed specifically for use with the same disc semiconductor. The result? The aluminum heat sink steady-state thermal impedance sink-to-ambient was 20% better (based on 1500 LFM); the weight, 38% less; and the cost, about half as much as the copper design. On the minus side, volume was 40% more. So, if a little extra space is available, an aluminum heat sink may be a better buy.

For higher output current at less cost, forced convection is the answer. A disc rectifier assembly at 1000 or 1500 LFM can handle more than twice its natural convection current rating. Likewise, a disc SCR assembly at 1000 or 1500 LFM can handle more than 2.5 times its natural convection current rating. Why buy more semiconductors than are really needed to do the job? A few fans and some baffling may allow for a substantial savings in system design costs. Use forced air in lieu of natural convection air when possible.

Water cooling

Water cooling is the most efficient type of cooling in general use today. While it may not be a practical solution to every designer's problems, more and more systems are being converted to water each year. Inherent advantages in size, weight and cost simply cannot be overlooked. Some manufacturers even quote jobs to their customers both ways—air and water—just to show the relative merits of water cooling. It keeps system costs down.

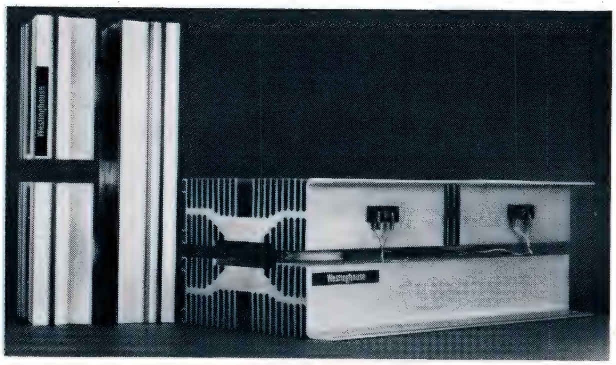


Fig. 3—Aluminum extrusion heat sinks such as these beat copper fin designs in several areas. Thermal ratings are often comparable and they offer lower weight and about 50% less cost. On the other hand, the copper design can be 40% smaller in volume. For best efficiency with either type, forced-air cooling should be used.

In order to optimize the water-cooled heat-sink's thermal efficiency, nearly-pure copper heat exchangers should be used. Copper alloys, bronze, aluminum, etc., generally have much lower thermal conductivities. Therefore, unlike most air-cooled heat sinks, copper water-cooled heat sinks do offer more output current per dollar than other types.

Typical examples of water-cooled copper heat sinks are shown in **Fig. 4**. When deliberating such devices, consider the following: One-piece construction guarantees against leaks. If the power tab is also a 1-piece casting, it becomes an integral part of the water jacket for high-power connections. Finally, R-C tabs are also sometimes offered as options on water jackets. This permits resistor and/or capacitor networks to be easily connected directly across each semiconductor.

Water and air: how do they compare?

Figs. 5 and **6** summarize the relative merits of water vs. air cooling. **Fig. 5** compares output current ratings for a 3-phase rectifier bridge with air cooling and water cooling for six different disc rectifier types. Likewise, **Fig. 6** compares the output current ratings for a 3-phase full-control bridge with air and water cooling for seven different disc SCR's. In each case, the water ratings are significantly better than air. In addition, consider that a water-cooled assembly and an air-cooled assembly utilizing the same disc device cost about the same. This means water cooling offers more output current/dollar.

To be specific, using a 1000A, Model T920 SCR, the water-cooled assembly (25°C water) will handle over four times the natural convection current rating and 1-1/2 times the 1000 linear-feet/minute forced-convection current rating of the air-cooled assembly (40°C ambient). In addition, the water-cooled unit is about one-third the weight, occupies only about 40% of the space, and costs about the same as the air-cooled one. Therefore, when heat exchangers are compared, water cooling is usually the most economical choice; forced convection air is next; and natural-convection air is last.

Should you build or buy?

Two of the most important resources in any company are manpower and money. The effectiveness of the utilization of these two resources, to a great extent, determines the company's degree of success. Therefore, a decision to build or buy an assembly should consider this. But often the decision is based solely upon volume. For low-volume requirements, the automatic

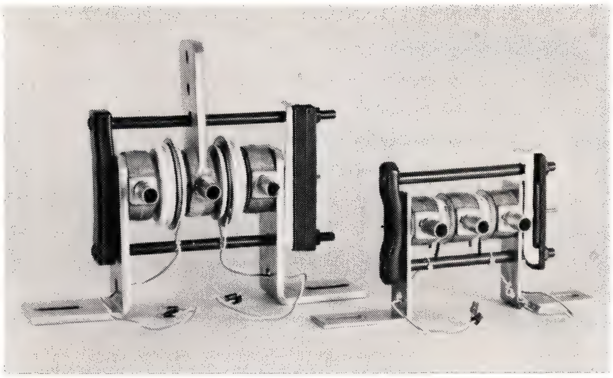


Fig. 4—Water-cooled disc assemblies are most effective when constructed out of copper. Optional features, such as hook-up tabs for passive components, greatly increase the utility of such systems.

determination is to buy the complete assembly; for high-volume requirements, to build them in-house. Unfortunately, this simple generalization is frequently wrong. The matter of building assemblies in-house, or buying a completely assembled module, is a complex problem, requiring inputs from many different departments.

One key question that should be answered is, how much does this assembly activity deviate from the normal line of business? That is, can the organization handle the assembly job efficiently without adversely affecting normal day-to-day operations? Also, since time can be a very limiting constraint, how soon will these assemblies be needed—prototypes, production build-up rates, etc.? Don't forget "out-of-pocket" investment costs, either. How much will the required raw materials, work-in-process, and finished assembly inventory, etc. cost? Above all, in any build or buy decision, do not neglect to consider opportunity costs. Could the required manpower needed for building assemblies be more productive and earn a greater return on investment in other programs?

Of course, engineering factors should not be overlooked when making a build or buy decision. Air and water-cooled disc assemblies must be clamped together to insure proper heat transfer to the sinks as well as to insure proper electrical contact. Insufficient mounting force can result in overheating due to higher forward voltage drop and higher thermal impedance. On the other hand, excess force can crack the silicon element. Both of these conditions will lead to device failure.

Selection of the proper size clamp and developing a good mounting procedure is essential. Preloading the clamp before it is actually used in the final application is desirable. Locating pins should be used, since they help center the disc for better load distribution. When assembling large-area devices requiring high clamping forces

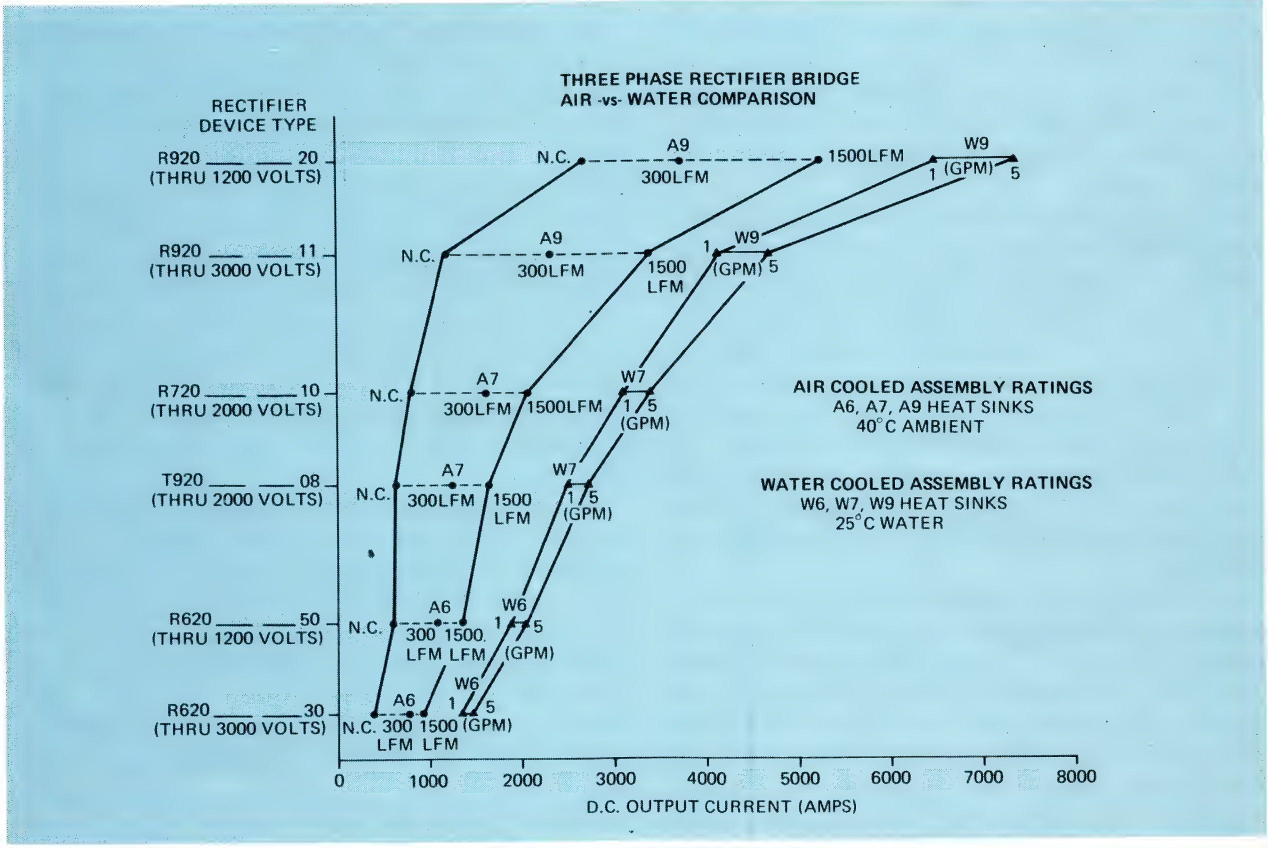


Fig. 5—Water wins over air when it comes to cooling semiconductors. Here output current ratings for six different rectifiers are compared when water and forced-air cooling are used.

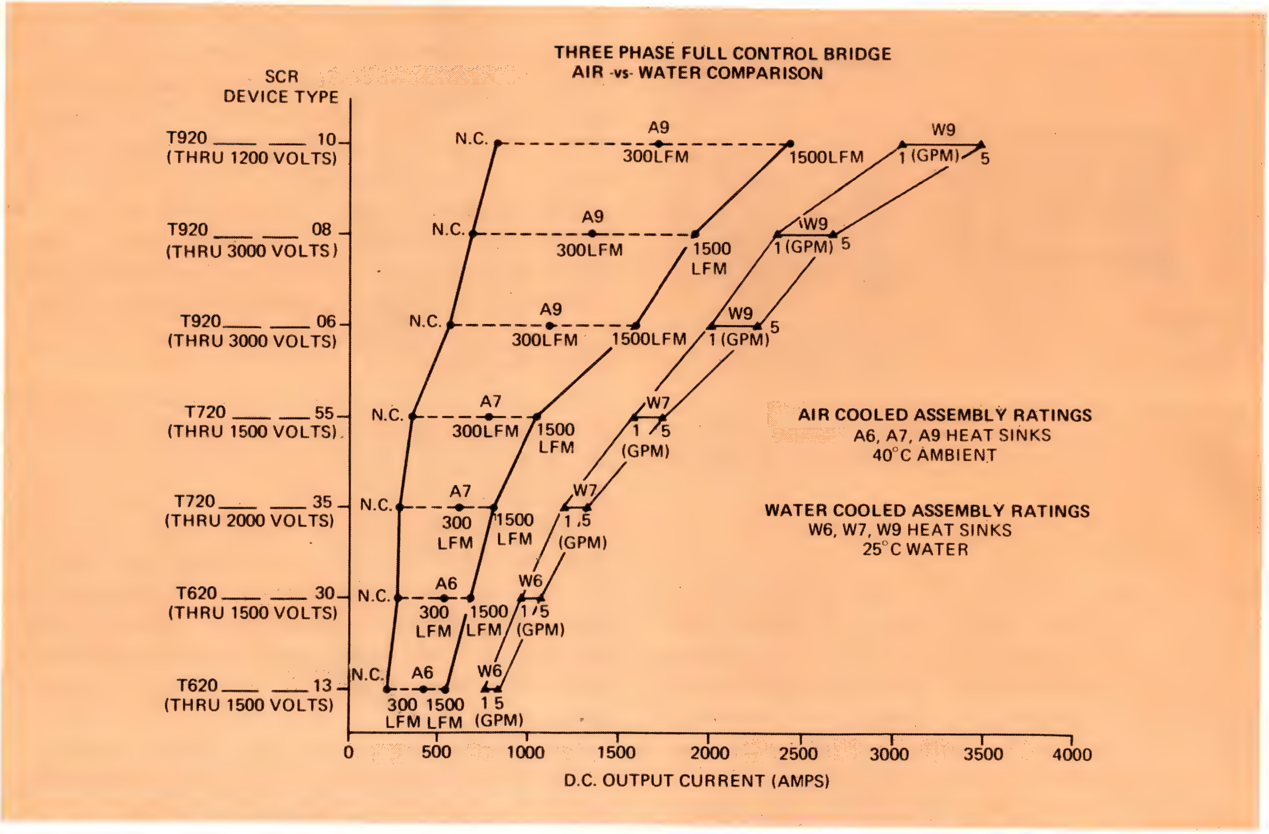


Fig. 6—Advantages of water cooling over air cooling include 30 to 40% more output current, over a 70% decrease in weight, a 60% decrease in space and more current/dollar. On the minus side, one must consider the plumbing and pump required. Air and water cooling are compared here for seven different disc SCR's.

(e.g., the T920/R920), clamp threads should be coated with either "Anti-Seize," or "Never Seez" compound. This will prevent any binding between the nut and clamp threads when force is being applied. (Either of these compounds can be purchased at a local automotive or plumbing supply center.)

Heat sink mounting surfaces should be flat, smooth and free from anodize or finishes. For example, aluminum extrusions should be spot-faced prior to mounting the disc power device. A thin film of a thermal-joint compound such as Alcoa #2 should be applied to both the device pole piece and heat sink mounting surface immediately prior to assembly. This increases the heat transfer from device to sink by filling small scratches and air gaps. It also tends to break down the oxide that often forms on the aluminum extrusion.

In summary, disc semiconductors and their associated heat exchangers, while certainly not fragile, do require careful, knowledgeable handling when they are combined in high-efficiency assemblies. Many elements must be considered and it can be expensive for a company to develop this expertise. Moreover, since newer and better fabrication techniques are continuously being developed, the company which is building assemblies in-house is well advised to keep up to date on the latest methods and procedures.

On the other hand, buying a complete assembly is not really a simple process, either. A specification must be developed; potential sources of supply identified; requests for quote issued; the resultant quotations reviewed and compared as to price, delivery, specifications and other relevant considerations; and finally a purchase order awarded to the successful bidder. This procedure costs time and money. Further, since companies with high volume, continuous production requirements usually carry some minimum inventory (safety stock) level, the costs associated with carrying this inventory (interest, manpower and facilities used) must not be forgotten.

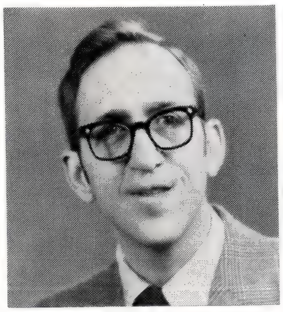
Balanced against these factors are three important advantages of a buy decision. First, component manufacturers usually have a very large stock of devices on hand. This enables them to match heat sinks and individual components for best performance. Second, when you buy the complete assembly, all ratings can be guaranteed. There is no need to manipulate the ratings of each part. Finally, when you get everything you need from one supplier, you can significantly simplify logistics problems and possibly save money through larger purchases.

With all these considerations in mind, the build or buy decision can now be made. Direct costs associated with each option should be totaled. Be sure that each cost item listed under one option also appears under the other option (even if the cost is zero) so that the resulting totals being compared are balanced. For example, if assembly shipping costs are included under the buy option, then the shipping costs associated with each component part should be included under the build option.

Totals should yield a fairly accurate estimate of the "out-of-pocket" costs associated with each option. However, judgement is the most important factor in the entire process. In addition to these "out-of-pocket" costs, indirect costs as well as the other nonquantifiable areas previously discussed should be considered in making the final decision. Ultimately, the correct build or buy decision is the one which leads to the most efficient utilization of all available resources: manpower, facilities and money.

Periodically, preferably every 12-18 months, previous build and buy decisions should be reviewed. Under latest conditions, is a change in strategy warranted? This review is especially important because economic and local market conditions change, anticipated production levels may be much lower or higher than originally projected, and/or original cost estimates used may no longer be relevant. Also, a previous build or buy decision may not necessarily be optimum for future jobs. Each project exhibiting differing characteristics should be considered on its own merits. Finally, remember that even if the resultant decision is to build rather than buy an assembly, the information gained from the necessary analysis will be well worth the effort. You will at least be certain that you're getting the most out of your power semiconductors.□

Author's biography



Woodson J. Savage, III, assembly products coordinator at Westinghouse's Semiconductor Div., handles all marketing functions for semiconductors mounted on heat exchangers. He received his BS in engineering physics and is currently attending the Executive MBA Program at the Univ. of Pittsburgh. Woody is an avid collector of antiques (early American and primitive furniture and artifacts) and also enjoys coin collecting, woodworking, travel and fine foods.

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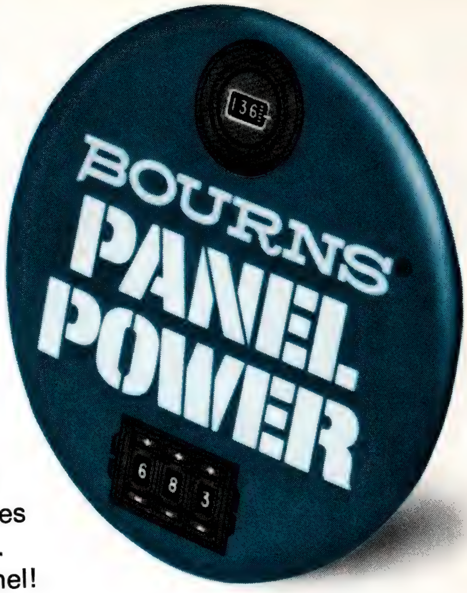

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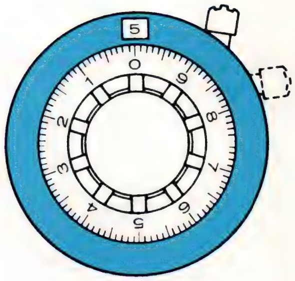

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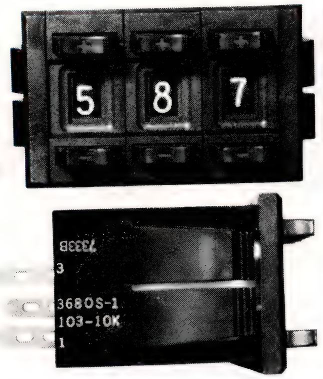

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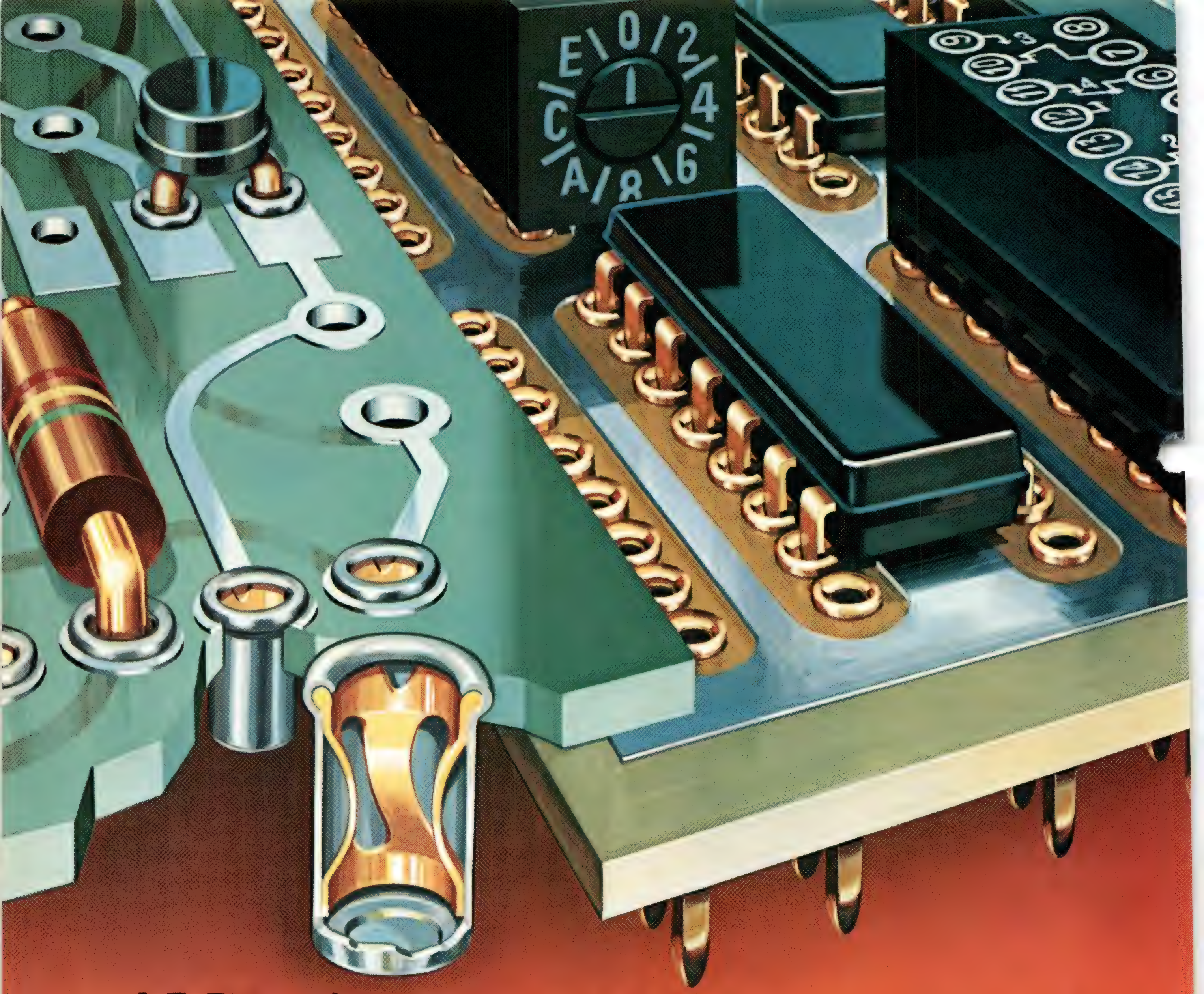

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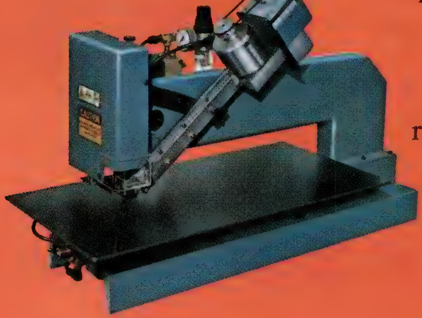

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Dual-beam: an often misunderstood type of oscilloscope

Known as dual-beam, dual-gun or split-beam, these special-purpose oscilloscopes are important design tools—if you understand them.

Vince Lutheran and **Bernie Floersch**, Tektronix Inc.

A frequent requirement in design work is to capture and simultaneously display on an oscilloscope cathode-ray tube (CRT) two or more signals. Various methods of accomplishing this have been developed over the years, with each having advantages and disadvantages. Choosing the best method for any given application, then, is largely a matter of understanding the different techniques.

Dual trace is least expensive

Of the various ways available to display multiple signals simultaneously, the most widely known and used is the dual-trace concept. Dual trace uses a single-electron-gun CRT—your conventional oscilloscope with one set of X plates for deflecting the beam horizontally and one set of Y plates for deflecting the beam vertically. With this method two traces are obtained by electronically switching between two input signals, so that the two signals time share the single electron beam on the X and Y plates. Typically there are two methods of switching: the chop mode and the alternate mode.

The chop mode (**Fig. 1**) uses a free-running oscillator to control an electronic switch. Thus, short segments of each input signal are displayed with a single gun and single set of deflection plates. A vertical separation control allows the two displays to be offset on the Y axis within the confines of the graticule display area. The resultant display thus consists of two segmented traces.

Since the oscillator controlling the switch is not synchronous with the display signal, chop mode causes no problem as long as input signals are repetitive, and the sweep speed is slow enough not to cause chop segments to be displayed. Both traces appear to be solid traces. However, if you look at two signals that occur only once, in other words are single shot, the segmentation in the display is clearly evident. Typically, the chopping oscillator runs at a 1 or 2 MHz rate, thereby severely limiting maximum useable sweep speed on such single-event signals.

In the alternate mode (**Fig. 2**), switching occurs at the end of each sweep. Therefore the two input signals are displayed alternately at a rate determined by sweep speeds used. This method is completely unuseable for two single-event signals since, as the event occurs, it triggers the first sweep and there isn't another event to trigger the second trace.

The major advantage of the dual-trace tech-

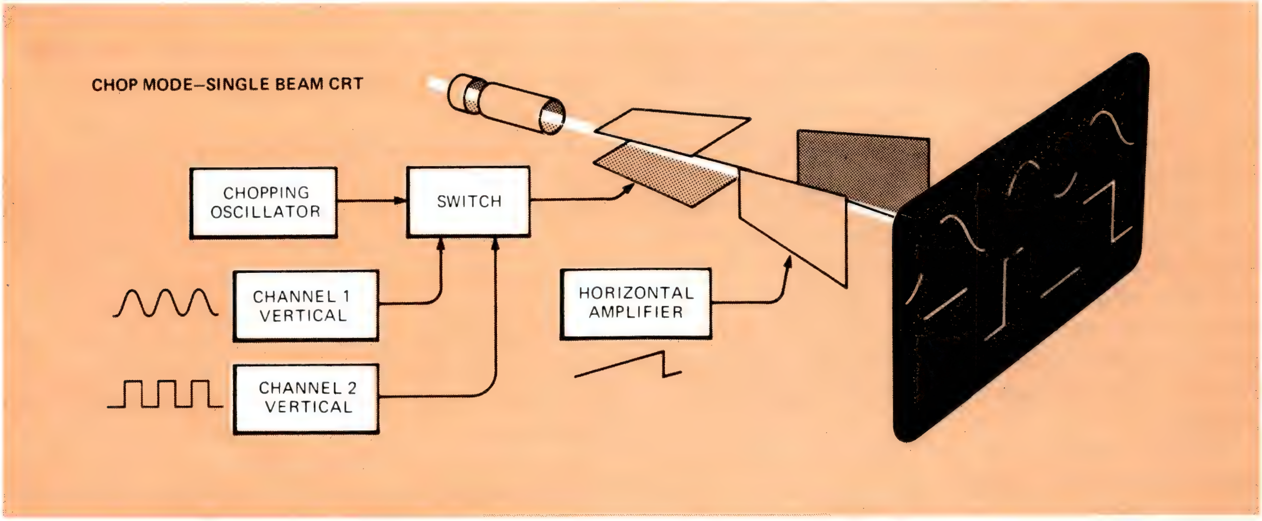


Fig. 1—Single-beam CRT using chop-mode switching shows definite display segmentation when the two signals are nonrepetitive.

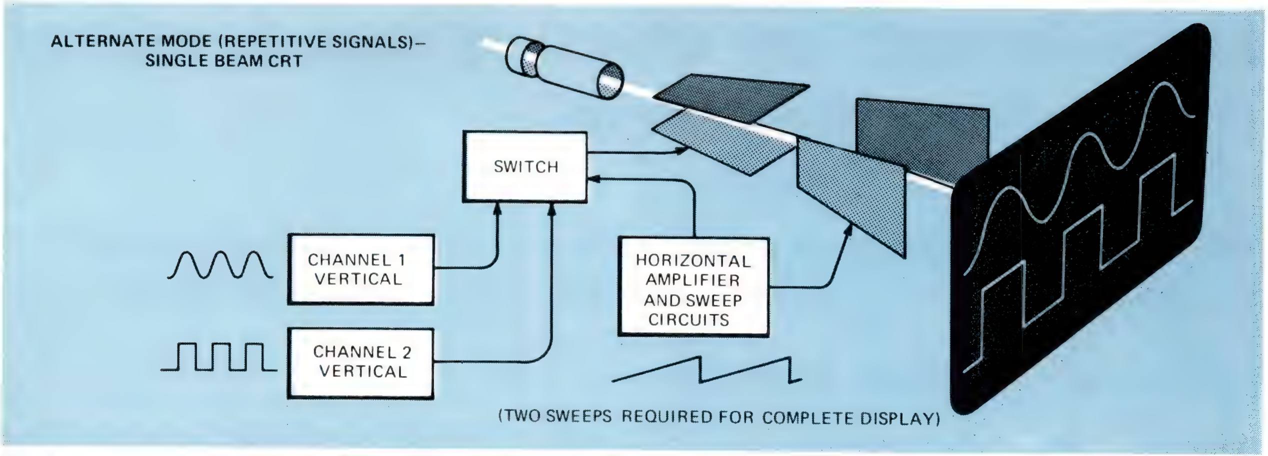

ALTERNATE MODE (REPETITIVE SIGNALS)–
SINGLE BEAM CRT
SWITCH
CHANNEL 1 VERTICAL
CHANNEL 2 VERTICAL
HORIZONTAL AMPLIFIER AND SWEEP CIRCUITS
(TWO SWEEPS REQUIRED FOR COMPLETE DISPLAY)

Fig. 2—Segmentation is eliminated when a single-beam CRT uses alternate-mode switching. Here, switching between signals occurs at the end of each sweep rather than at a rate determined by a free-running oscillator, as in **Fig. 1**.

nique, which is generally standard on better oscilloscopes, is its lower cost when compared to other methods of displaying two signals simultaneously. Dual trace, though, does have definite disadvantages, the primary one being trigger ambiguity in the alternate mode. Two complex signals, unrelated in time, create problems in triggering or in determining coincident time relationships. Most modern oscilloscopes provide a trigger-mode switch that allows triggering from either vertical channel, or from a composite of the two. If the two inputs are unrelated in time, you can only trigger on one, with its resulting display being stable. The second display, however, will appear to be free-running.

A second dual-trace disadvantage is signal loss due to the chopping rate or the alternate switching rate. If the signal is being chopped, each trace is displaying only half of the true signal, effectively leaving holes in the traces which must be interpolated. Furthermore, switching transients (which occur during switching between the two signals) blank the Z axis. This further increases signal loss.

The third disadvantage of dual trace is that trace brightness is reduced in either mode. This follows because a single beam is being shared between two signals. Each display, then, is only going to have half the light output.

One limitation of dual trace is phase error in the alternate mode with composite triggering. With the beam switching between two vertical channels and each channel providing triggering for its corresponding trace, there is no common time reference point. Thus, with different trigger signals in each case, the time relationship is ambiguous.

Another limitation to chopped, dual-trace operation is chopping rate of the switching oscillator. This limit occurs when signal frequency catches that of the oscillator (typically 1 or 2 MHz). This means that for a single-shot presentation where two signals time share the beam, sweep speed must be slower than 1 μsec in order to retain needed information. Even though the chopping oscillator runs at 1 MHz, the effective limit is much lower. Thus, single-shot applications for dual-trace oscilloscopes require very slow signals.

In essence, then, dual-trace techniques are effective from both technology and cost consideration for almost all repetitive signal applications. However, for multiple traces of single-shot events, some form of dual-beam oscilloscope becomes mandatory.

What, really, is dual beam?

Frequently, confusion reigns during discussions of the dual-beam concept. This is because the term loosely covers three different types of multi-beamed oscilloscopes: split-beam, dual-beam and dual-gun. In practice, any of the three may be labelled dual beam. For example, the Tektronix 7844 "dual-beam oscilloscope" is actually a "dual-gun" instrument. Users should be aware of the differences between the three types, however, since each has definite advantages and disadvantages.

A split-beam concept CRT (Fig. 3) has a single electron source up through the second anode, at which point the beam is split. Each beam is then sent through independent vertical deflection systems and through a common horizontal deflection system. Independent horizontal systems have never become cost effective for split-beam CRT's. Dual-gun instruments, described later, fill any such application need without split-beam limitations.

Some of the earlier split-beam CRT's were single ended: one plate of the vertical deflection system was common to both beams. Each beam had independent deflections but shared the

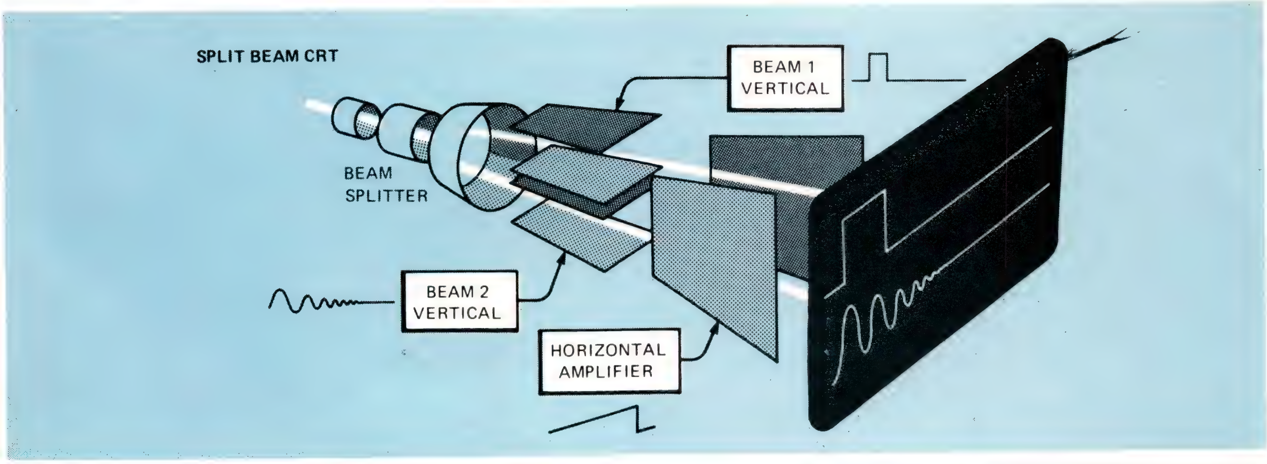


Fig. 3—Split-beam CRT's use a single electron source, which is split at the second anode. Each beam has an independent vertical deflection system, but shares a common horizontal deflection system.

common center plate. Newer split-beam designs are double-ended with two fully separate sets of vertical deflection plates.

Split beam represents a giant stride over dual trace in that time sharing is no longer involved. The traces are displayed 100% of the time. Split beam also overcomes, item for item, the other major disadvantages of dual trace: there is no signal loss nor extensive light loss due to time sharing; a single horizontal position control maintains time registration on all displays; and the single horizontal amplifier minimizes the time adjustments for the split beam.

Among split-beam limitations is lower writing speed due to only one electron source being available for both beams. Also, the single electron source ties both beams to a common intensity control, again a feature which may inconvenience the operator. If Z-axis modulation is needed for a given application, this single electron source prevents independent modulation.

The second of the dual-beam-type oscilloscopes is that concept properly labelled as dual beam. **Dual-beam CRT's (Fig. 4)** use two electron sources, two independent vertical deflection systems and a common set of horizontal deflection plates. They overcome the same dual-trace disadvantages as do split-beam oscilloscopes and, additionally, overcome the electron source limitations of split beam. Since they use a single horizontal amplifier, a single time base and a single trigger circuit, dual-beam units are less costly than later developed dual-gun instruments.

The third dual-beam concept, and the one representing the most advanced technology, is **the dual-gun concept (Fig. 5)**. This CRT has two totally independent systems: two electron sources, two vertical deflection systems and two horizontal deflection systems. Only the display screen is shared by both beam systems.

Undoubtedly, the principal unique advantage of a dual-gun oscilloscope is its ability to display one signal—or a single event—in real time at two different sweep speeds. Almost as important is the dual gun's ability to trigger each sweep separately. Thus displays of two signals, unrelated in time, are stable.

In practice, all dual-gun oscilloscopes have two vertical amplifier sections, two horizontal amplifier sections and two horizontal time bases.

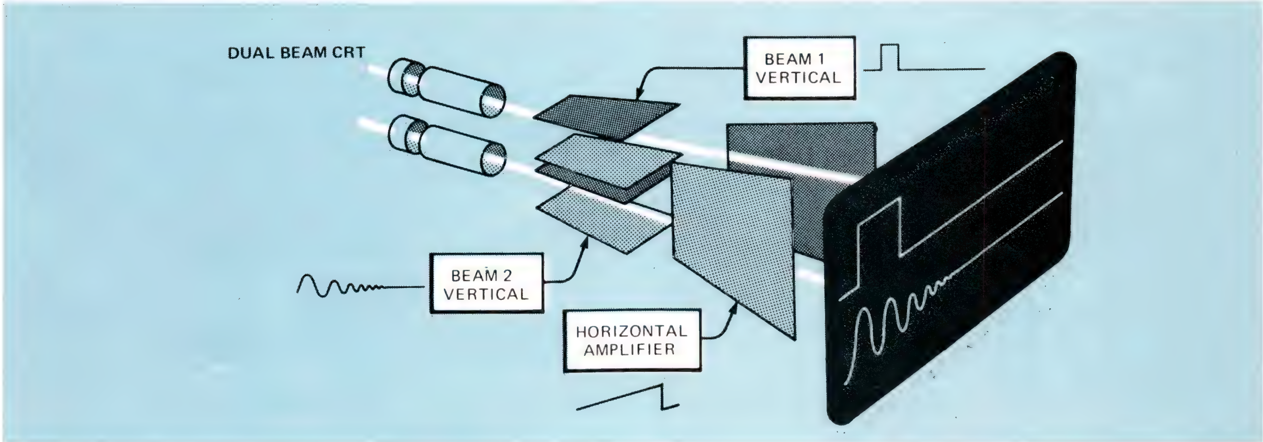


Fig. 4—Dual-beam CRT's differ from split-beam ones in that they have two independent electron sources. Deflection systems are the same.

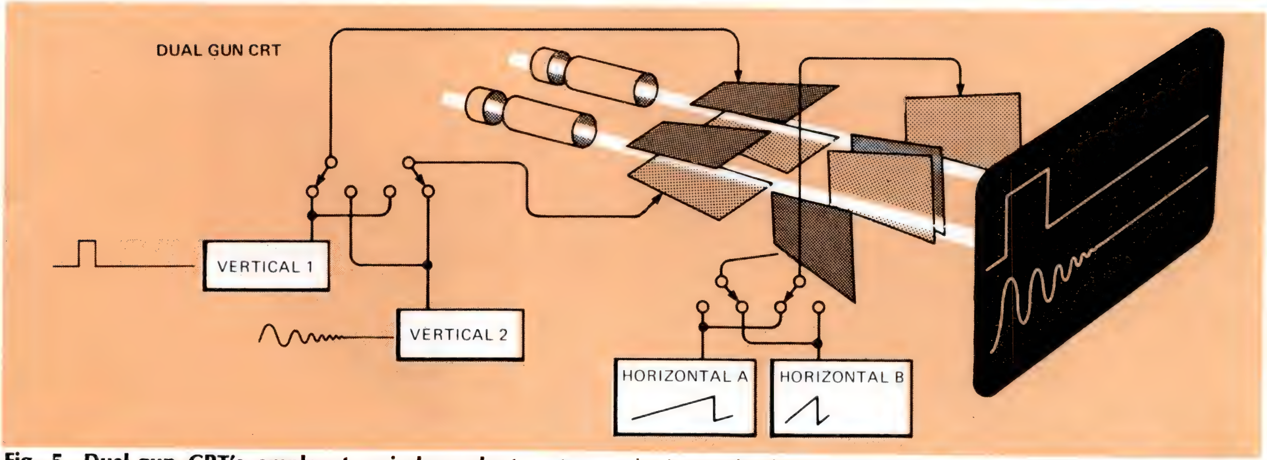


Fig. 5—Dual-gun CRT's employ two independent systems, sharing only the display screen. Each beam can be triggered separately—at different sweep speeds—thus making this the most versatile technique.

Selective cross coupling is also available on newer dual-gun oscilloscopes so that either or both beams can be driven by any combination of vertical or horizontal systems.

A primary disadvantage of the dual-gun concept is that each beam has a separate horizontal position control. When making time-related measurements, the operator has to register each beam with the other using two separate controls. This can be an inconvenience when compared to dual-beam or split-beam concepts.

Dual-beam applications are varied

In general, anyone who needs to look at two or more fast, nonrecurring events, or very slow repetition-rate events, should consider dual beams. And, for most applications, the dual-beam oscilloscope should be augmented with a camera for a permanent record.

The following paragraphs illustrate the wide variety of applications possible with dual-beam oscilloscopes. They describe some actual areas where the unique capabilities of dual beams are put to use.

Collisionless shock wave experiments: In plasma shock-wave experiments (**Fig. 6**) using a ruby Q-switch laser, the signal displayed represents laser-beam intensity with a duration of 20 nsec, a risetime of 10 nsec or less and an amplitude of 5 mV. One signal origin is scattered light from plasma when hit by a laser beam through a photomultiplier amplifier. The second signal origin is a display of the laser light portion of the incident pulse.

Plasma research: Technology in this field has progressed to a point where kilowatts of power can be switched by way of a plasma arc in less than 1 μsec. Here, current and voltage waveforms of nonlinear switching are displayed on dual presentations. An alternate solution to this situation could employ a dual-trace presentation using a very high-speed chopper. This, though, would create considerable problems due to the chopping transients in the oscilloscope's electronic switch.

Switch design: Switch designers need dual beams for single-sweep examinations of instantaneous power consumed during the switch-

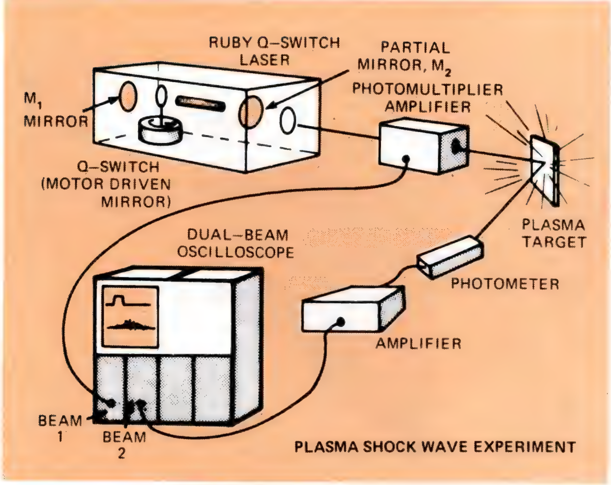


Fig. 6—Plasma shock wave experiment is an ideal application for dual-beam oscilloscopes.

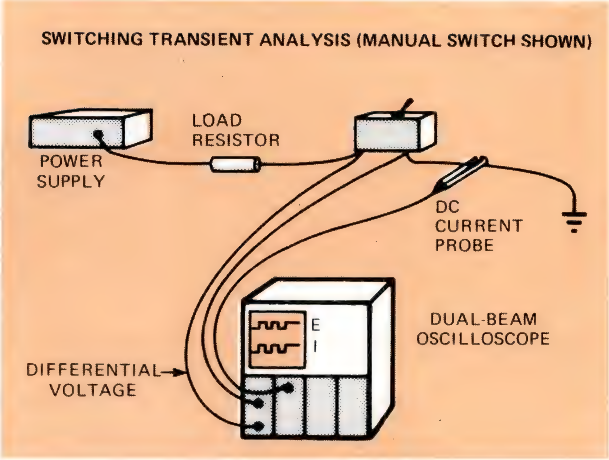


Fig. 7—Switching transient analysis of mechanical switches, where power is consumed only during actual switching, requires a dual-beam oscilloscope for measuring power.

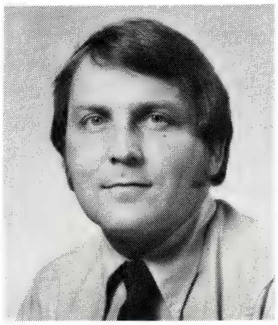
ing event. This is needed because a switching device consumes power only while it is switching. When the device is ON, it has low, or no, impedance; therefore it is consuming little or no power. When the device is OFF, it has high impedance, again consuming no power. For reasons of power dissipation of the device alone, the designer has to know the instantaneous power during the time the device is switching. These devices typically switch in the sub-nanosecond range. Therefore, simultaneous voltage and current oscilloscope waveforms are the only feasible means of power measurement (**Fig. 7**).

Medical research: This is a long-standing applications area for dual beam. For example, a researcher may want to stimulate a nerve and observe the reaction. Due to the response time of the nerve itself, this becomes essentially a single-shot application. One oscilloscope beam displays the stimulus pulse and the second beam displays the nerve reaction. Here the time coincidence is the important parameter.

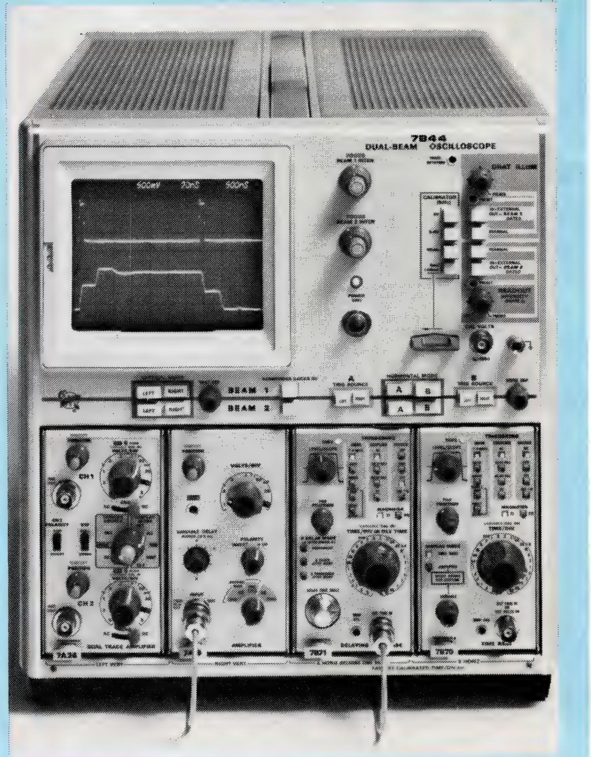
Another area of medical application involves looking at a response or a biological phenomenon, whether the phenomenon is stimulated or not, on two grossly different time scales. One time scale looks at the overall reaction, while the other display narrows the time down to a very small window. Perhaps it even uses some of the available vertical signal processing, such as differential, to look at small amplitudes as well as small time frames. Muscle artifact measurements fall into this category. □

Authors' biographies

Bernard Floersch is a Marketing Staff Engineer for the Laboratory Oscilloscope Group at Tektronix, Inc. in Beaverton, Oregon. A graduate of Central Technical Institute in Kansas City, MO, Bernie has been involved in instrument marketing for 14 years.



Vincent Lutheran is a Program Manager for the Laboratory Oscilloscope Group, also at Tektronix' Beaverton plant. He holds a BSEE degree from University of Maryland, and is a member of Tau Beta Pi and Eta Kappa Nu.



The 7844 is a 400-MHz dual-gun mainframe that can accommodate more than 30 plug-ins. Normally configured with two vertical amplifiers and two time bases, it could as easily combine one vertical amplifier and one time base for one beam, while a spectrum analyzer drives the second beam. Shown on the screen is application of cross over. One input, through one probe, is simultaneously displayed at two different sweep speeds.

Evolution of the dual-beam concept

Dual trace was the first technique for displaying two signals simultaneously and still is the most widely used. However, frequency limitations imposed by time sharing demanded two dedicated beams, which led to the development of dual-beam CRT's and later dual-gun CRT's.

Back in the 1950's, the Tektronix Models 555 and 551 oscilloscopes were developed, both with 25-MHz bandwidth. The 551 used a dual-beam CRT, while the 555 was the first dual-gun instrument. Additional instruments followed, increasing the dual-beam bandwidth to 1 MHz and the dual-gun bandwidth to 10 MHz. The last dual-beam instrument to be introduced for many years was the Tektronix 556, a 50-MHz oscilloscope which made its debut in 1965. With the recent introduction of the 400-MHz 7844 dual-gun oscilloscope it appears that dual beams are again abreast of oscilloscope state-of-the-art.

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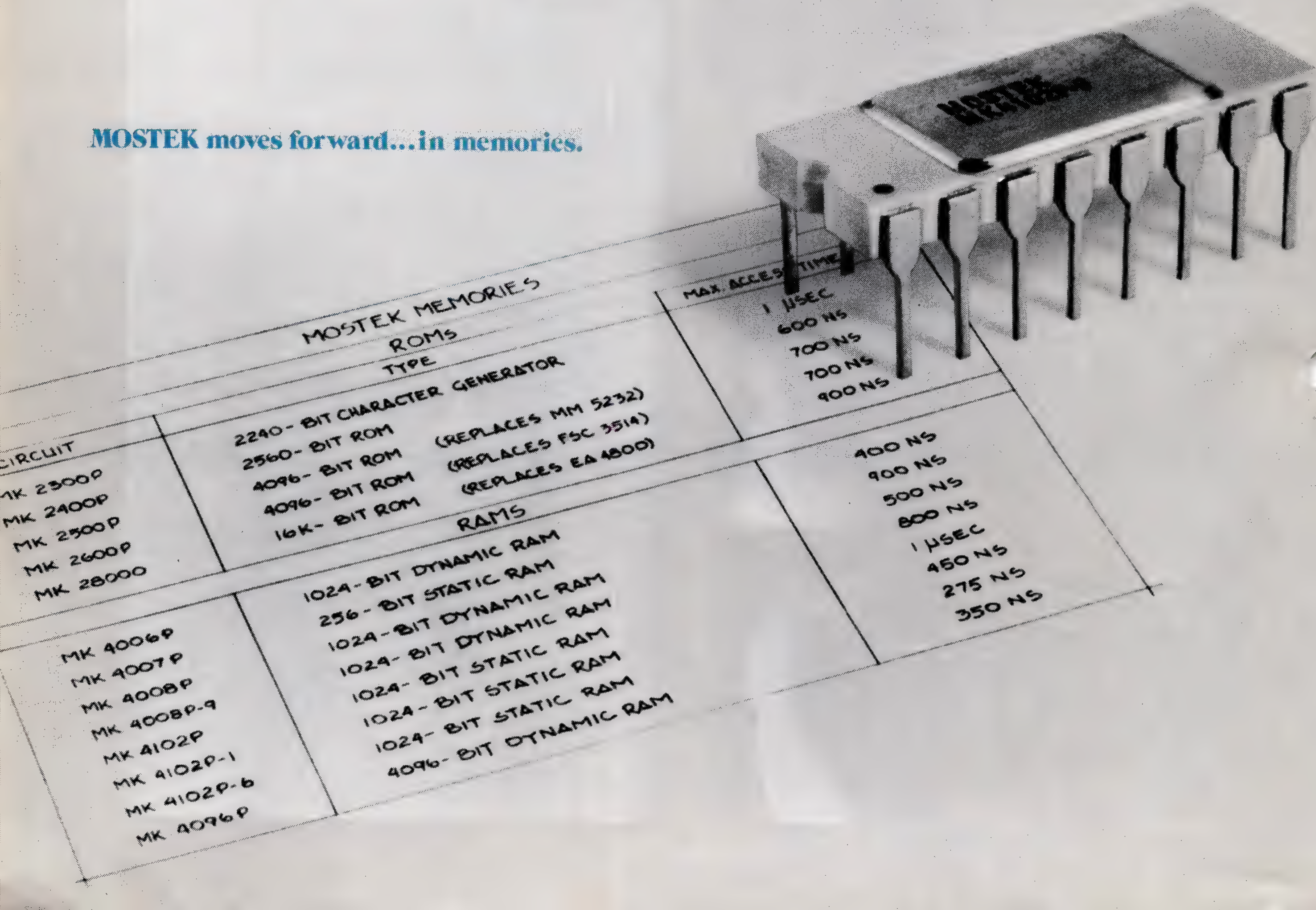

MOSTEK MEMORIES

IRCUIT	TYPE	MAX ACCESS TIME
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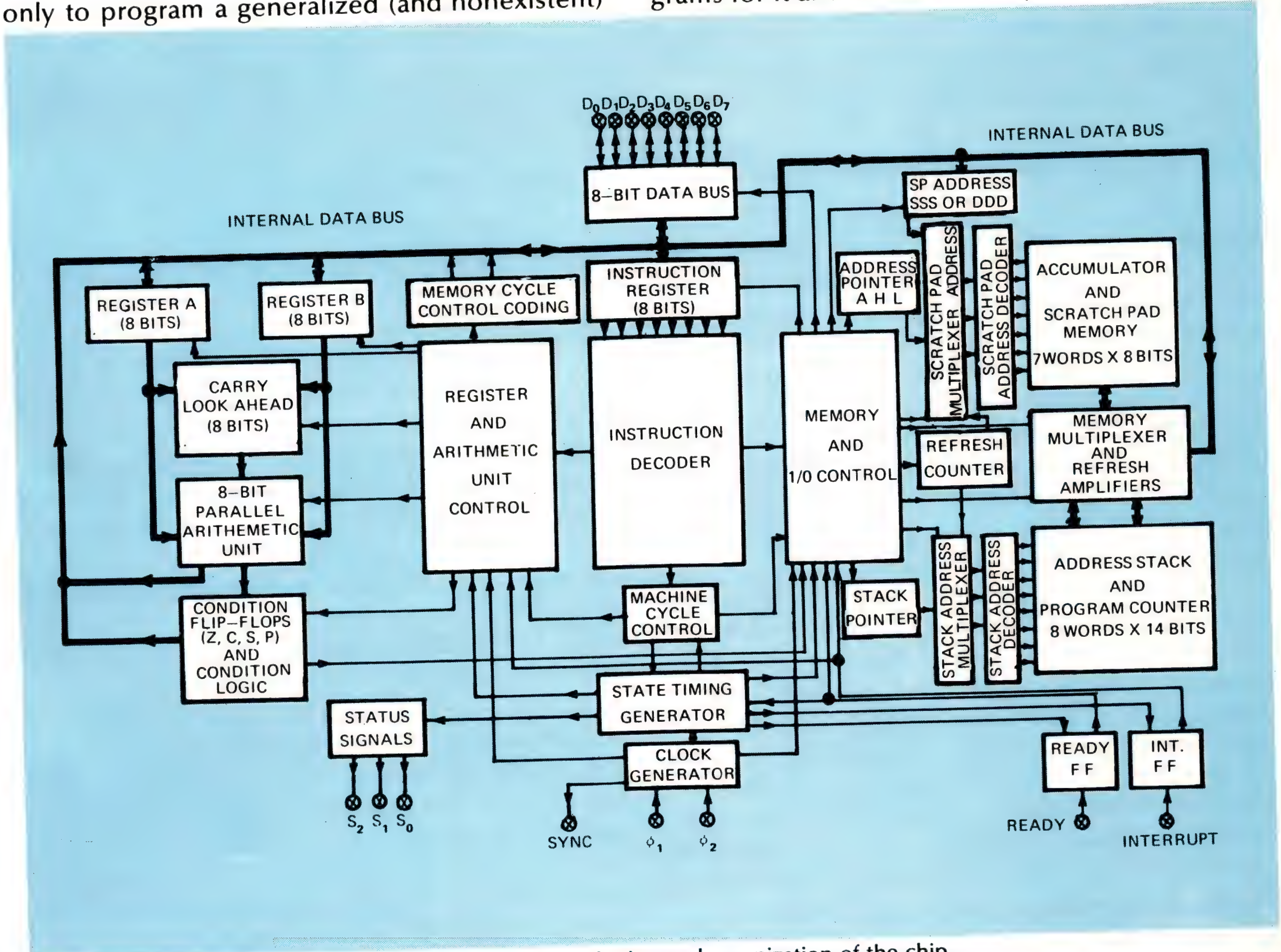
MK 2300P	2240- BIT CHARACTER GENERATOR	1 µSEC
MK 2400P	2560- BIT ROM (REPLACES MM 5232)	600 NS
MK 2500P	4096- BIT ROM (REPLACES FSC 3514)	700 NS
MK 2600P	4096- BIT ROM (REPLACES EA 4800)	700 NS
MK 28000	16K- BIT ROM	900 NS
	RAMs	
MK 4006P	1024- BIT DYNAMIC RAM	400 NS
MK 4007P	256- BIT STATIC RAM	900 NS
MK 4008P	1024- BIT DYNAMIC RAM	500 NS
MK 4008P-9	1024- BIT DYNAMIC RAM	800 NS
MK 4102P	1024- BIT STATIC RAM	1 µSEC
MK 4102P-1	1024- BIT STATIC RAM	450 NS
MK 4102P-6	1024- BIT STATIC RAM	275 NS
MK 4096P	4096- BIT DYNAMIC RAM	350 NS

Designer's Guide to: Software for the hardware designer—Part II

Programming microprocessors is not as easy as you might expect. Here's the way to program at least one popular type.

John Bond, Associate Editor

Programming a microprocessor (as with any computer) is dependent on the particular machine. It does no good to consider it in a general way since the would-be programmer would learn only to program a generalized (and nonexistent) sort of microprocessor. Try to debug your programs on that! So there is really only one way to get at the subject—pick a specific unit, see how it works, examine the instruction set, write programs for it and consider how you're going to get



D0 D1 D2 D3 D4 D5 D6 D7
INTERNAL DATA BUS
8-BIT DATA BUS
INTERNAL DATA BUS
SP ADDRESS SSS OR DDD
REGISTER A (8 BITS)
REGISTER B (8 BITS)
MEMORY CYCLE CONTROL CODING
INSTRUCTION REGISTER (8 BITS)
ADDRESS POINTER A H L
SCRATCH PAD MULTIPLEXER ADDRESS
SCRATCH PAD ADDRESS DECODER
ACCUMULATOR AND SCRATCH PAD MEMORY 7WORDS X 8 BITS
CARRY LOOK AHEAD (8 BITS)
REGISTER AND ARITHMETIC UNIT CONTROL
INSTRUCTION DECODER
MEMORY AND 1/0 CONTROL
REFRESH COUNTER
MEMORY MULTIPLEXER AND REFRESH AMPLIFIERS
8-BIT PARALLEL ARITHEMETIC UNIT
STACK ADDRESS MULTIPLEXER
STACK ADDRESS DECODER
ADDRESS STACK AND PROGRAM COUNTER 8 WORDS X 14 BITS
CONDITION FLIP-FLOPS (Z, C, S, P) AND CONDITION LOGIC
MACHINE CYCLE CONTROL
STACK POINTER
STATE TIMING GENERATOR
STATUS SIGNALS
CLOCK GENERATOR
READY FF
INT. FF
S2 S1 S0
SYNC
φ1
φ2
READY
INTERRUPT

Fig. 1—Block diagram of the 8008 microprocessor shows the internal organization of the chip.

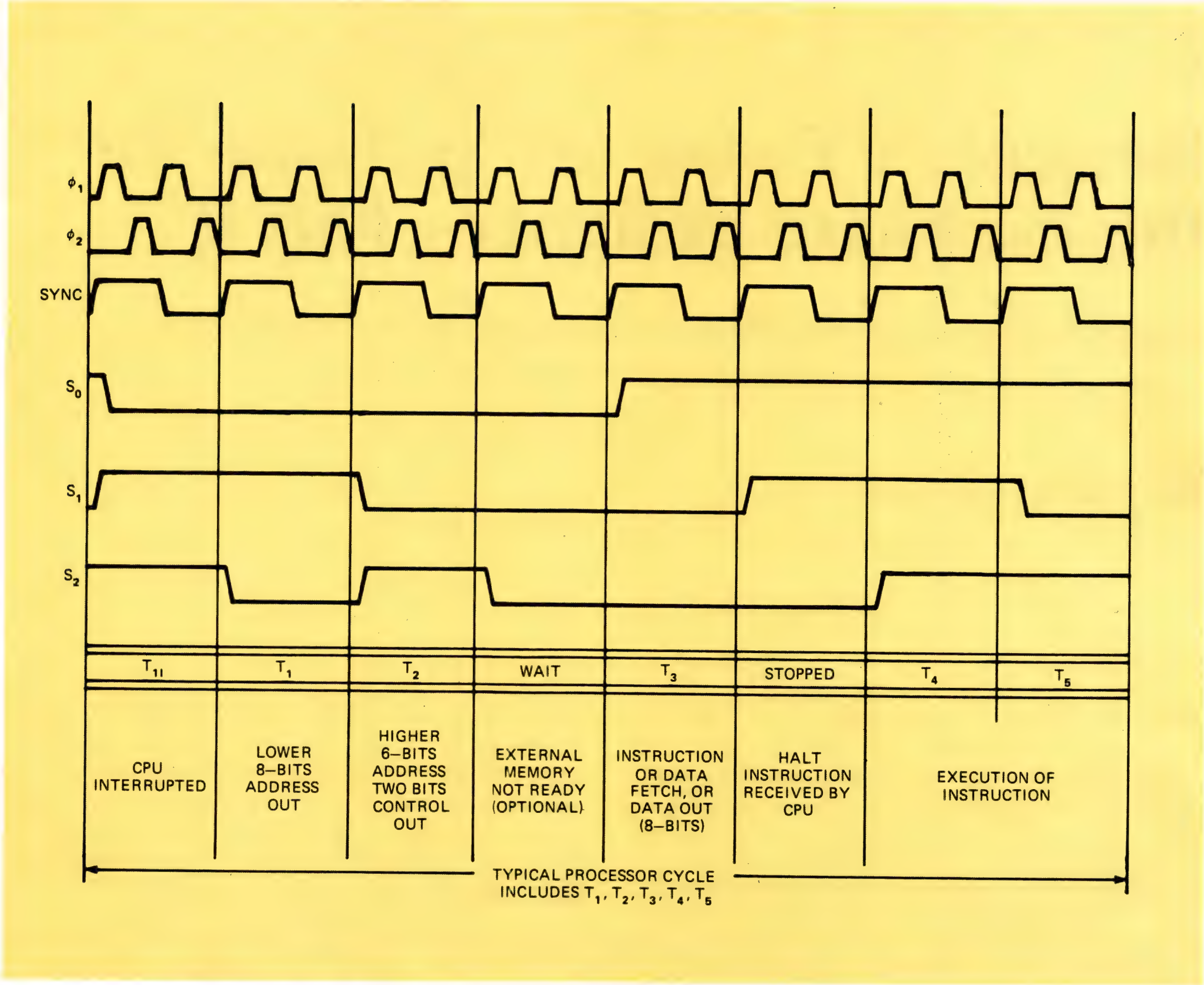

φ1
φ2
SYNC
S0
S1
S2
T11
T1
T2
WAIT
T3
STOPPED
T4
T5
CPU INTERRUPTED
LOWER 8–BITS ADDRESS OUT
HIGHER 6–BITS ADDRESS TWO BITS CONTROL OUT
EXTERNAL MEMORY NOT READY (OPTIONAL)
INSTRUCTION OR DATA FETCH, OR DATA OUT (8–BITS)
HALT INSTRUCTION RECEIVED BY CPU
EXECUTION OF INSTRUCTION
TYPICAL PROCESSOR CYCLE INCLUDES T1, T2, T3, T4, T5

Fig. 2—Basic instruction cycle of the 8008 indicates the five states T_1 through T_5, of a typical processor cycle.

the programs into it. The only way to do this with any success is to have a microprocessor and supporting equipment to play with. You can't do it very well as a purely paper exercise.

Having said all that, we will proceed to give you future programmer-engineers a purely paper insight into the technique. Whether or not you finally become competent at it will depend on how much you play with your microprocessor. Because if software is the way to good design, hardware is the only route to software.

The particular hardware that we've chosen to write about is the Intel MCS-8, built around the 8008 processor chip. This 8-bit μP has been around for quite a while and has been sold in large numbers. Even more important, the MCS-8 has been supported with a considerable amount of software for a microprocessor. Whether you use this device or some other, you'll find some useful principles embodied in the following discussion of software for hardware designers.

In the beginning there was a chip

The Intel 8008 processor chip is the heart of the MCS-8 microcomputer. Its organization (**Fig. 1**) and timing (**Fig. 2**) determine what sort of instruction set any computer built with this chip must have. That instruction set (**Table 1**) is the basic stuff out of which all programs must be assembled.

But computers do not live by processors alone. It takes a lot of off-chip electronics to make a micro. The basic MCS-8 has considerably more to it as can be seen from the block diagram (**Fig. 3**). Prototyping systems are available to help develop MCS-8 hardware and software for specific applications. The most elegant of these is the Intellec 8 which is almost a minicomputer in itself.

A minimum system required to work out programs might include the following: an ASR-33 Teletype™, MCB 8-10 interface/control module (assembled interconnect, display and control switches for SIM8-01 and MP7-03), MP7-03 pROM programmer card and a SIM 8-01 prototyping card (this is a basic MCS-8 set up for ease of software development). In addition to this, a designer would probably need at least four unprogrammed

MCS–8™ Instruction Set

INDEX REGISTER INSTRUCTIONS

The load instructions do not affect the flag flip-flops. The increment and decrement instructions affect all flip-flops except the carry.

MNEMONIC	MINIMUM STATES REQUIRED	INSTRUCTION CODE			DESCRIPTION OF OPERATION
		$D_7 D_6$	$D_5 D_4 D_3$	$D_2 D_1 D_0$	
(1) Lr_1r_2	(5)	1 1	D D D	S S S	Load index register r_1 with the content of index register r_2.
(2) LrM	(8)	1 1	D D D	1 1 1	Load index register r with the content of memory register M.
LMr	(7)	1 1	1 1 1	S S S	Load memory register M with the content of index register r.
(3) LrI	(8)	0 0 B B	D D D B B B	1 1 0 B B B	Load index register r with data B . . . B.
LMI	(9)	0 0 B B	1 1 1 B B B	1 1 0 B B B	Load memory register M with data B . . . B.
INr	(5)	0 0	D D D	0 0 0	Increment the content of index register r (r ≠ A).
DCr	(5)	0 0	D D D	0 0 1	Decrement the content of index register r (r ≠ A).

ACCUMULATOR GROUP INSTRUCTIONS

The result of the ALU instructions affect all of the flag flip-flops. The rotate instructions affect only the carry flip-flop.

MNEMONIC	MINIMUM STATES REQUIRED	$D_7 D_6$	$D_5 D_4 D_3$	$D_2 D_1 D_0$	DESCRIPTION OF OPERATION
ADr	(5)	1 0	0 0 0	S S S	Add the content of index register r, memory register M, or data B . . . B to the accumulator. An overflow (carry) sets the carry flip-flop.
ADM	(8)	1 0	0 0 0	1 1 1	
ADI	(8)	0 0 B B	0 0 0 B B B	1 0 0 B B B	
ACr	(5)	1 0	0 0 1	S S S	Add the content of index register r, memory register M, or data B . . . B to the accumulator with carry. An overflow (carry) sets the carry flip-flop.
ACM	(8)	1 0	0 0 1	1 1 1	
ACI	(8)	0 0 B B	0 0 1 B B B	1 0 0 B B B	
SUr	(5)	1 0	0 1 0	S S S	Subtract the content of index register r, memory register M, or data B . . . B from the accumulator. An underflow (borrow) sets the carry flip-flop.
SUM	(8)	1 0	0 1 0	1 1 1	
SUI	(8)	0 0 B B	0 1 0 B B B	1 0 0 B B B	
SBr	(5)	1 0	0 1 1	S S S	Subtract the content of index register r, memory register M, or data B . . . B from the accumulator with borrow. An underflow (borrow) sets the carry flip-flop.
SBM	(8)	1 0	0 1 1	1 1 1	
SBI	(8)	0 0 B B	0 1 1 B B B	1 0 0 B B B	
NDr	(5)	1 0	1 0 0	S S S	Compute the logical AND of the content of index register r, memory register M, or data B . . . B with the accumulator.
NDM	(8)	1 0	1 0 0	1 1 1	
NDI	(8)	0 0 B B	1 0 0 B B B	1 0 0 B B B	
XRr	(5)	1 0	1 0 1	S S S	Compute the EXCLUSIVE OR of the content of index register r, memory register M, or data B . . . B with the accumulator.
XRM	(8)	1 0	1 0 1	1 1 1	
XRI	(8)	0 0 B B	1 0 1 B B B	1 0 0 B B B	
ORr	(5)	1 0	1 1 0	S S S	Compute the INCLUSIVE OR of the content of index register r, memory register m, or data B . . . B with the accumulator .
ORM	(8)	1 0	1 1 0	1 1 1	
ORI	(8)	0 0 B B	1 1 0 B B B	1 0 0 B B B	
CPr	(5)	1 0	1 1 1	S S S	Compare the content of index register r, memory register M, or data B . . . B with the accumulator. The content of the accumulator is unchanged.
CPM	(8)	1 0	1 1 1	1 1 1	
CPI	(8)	0 0 B B	1 1 1 B B B	1 0 0 B B B	
RLC	(5)	0 0	0 0 0	0 1 0	Rotate the content of the accumulator left.
RRC	(5)	0 0	0 0 1	0 1 0	Rotate the content of the accumulator right.
RAL	(5)	0 0	0 1 0	0 1 0	Rotate the content of the accumulator left through the carry.
RAR	(5)	0 0	0 1 1	0 1 0	Rotate the content of the accumulator right through the carry.

PROGRAM COUNTER AND STACK CONTROL INSTRUCTIONS

MNEMONIC	MINIMUM STATES REQUIRED	$D_7 D_6$	$D_5 D_4 D_3$	$D_2 D_1 D_0$	DESCRIPTION OF OPERATION
(4) JMP	(11)	0 1 B_2 B_2 X X	X X X B_2 B_2 B_2 B_3 B_3 B_3	1 0 0 B_2 B_2 B_2 B_3 B_3 B_3	Unconditionally jump to memory address $B_3 \ldots B_3B_2 \ldots B_2$.
(5) JFc	(9 or 11)	0 1 B_2 B_2 X X	0 C_4 C_3 B_2 B_2 B_2 B_3 B_3 B_3	0 0 0 B_2 B_2 B_2 B_3 B_3 B_3	Jump to memory address $B_3 \ldots B_3B_2 \ldots B_2$ if the condition flip-flop c is false. Otherwise, execute the next instruction in sequence.
JTc	(9 or 11)	0 1 B_2 B_2 X X	1 C_4 C_3 B_2 B_2 B_2 B_3 B_3 B_3	0 0 0 B_2 B_2 B_2 B_3 B_3 B_3	Jump to memory address $B_3 \ldots B_3B_2 \ldots B_2$ if the condition flip-flop c is true. Otherwise, execute the next instruction in sequence.
CAL	(11)	0 1 B_2 B_2 X X	X X X B_2 B_2 B_2 B_3 B_3 B_3	1 1 0 B_2 B_2 B_2 B_3 B_3 B_3	Unconditionally call the subroutine at memory address $B_3 \ldots B_3B_2 \ldots B_2$. Save the current address (up one level in the stack).
CFc	(9 or 11)	0 1 B_2 B_2 X X	0 C_4 C_3 B_2 B_2 B_2 B_3 B_3 B_3	0 1 0 B_2 B_2 B_2 B_3 B_3 B_3	Call the subroutine at memory address $B_3 \ldots B_3B_2 \ldots B_2$ if the condition flip-flop c is false, and save the current address (up one level in the stack.) Otherwise, execute the next instruction in sequence.
CTc	(9 or 11)	0 1 B_2 B_2 X X	1 C_4 C_3 B_2 B_2 B_2 B_3 B_3 B_3	0 1 0 B_2 B_2 B_2 B_3 B_3 B_3	Call the subroutine at memory address $B_3 \ldots B_3B_2 \ldots B_2$ if the condition flip-flop c is true, and save the current address (up one level in the stack). Otherwise, execute the next instruction in sequence.
RET	(5)	0 0	X X X	1 1 1	Unconditionally return (down one level in the stack).
RFc	(3 or 5)	0 0	0 C_4 C_3	0 1 1	Return (down one level in the stack) if the condition flip-flop c is false. Otherwise, execute the next instruction in sequence.
RTc	(3 or 5)	0 0	1 C_4 C_3	0 1 1	Return (down one level in the stack) if the condition flip-flop c is true. Otherwise, execute the next instruction in sequence.
RST	(5)	0 0	A A A	1 0 1	Call the subroutine at memory address AAA000 (up one level in the stack).

INPUT/OUTPUT INSTRUCTIONS

MNEMONIC	MINIMUM STATES REQUIRED	$D_7 D_6$	$D_5 D_4 D_3$	$D_2 D_1 D_0$	DESCRIPTION OF OPERATION
INP	(8)	0 1	0 0 M	M M 1	Read the content of the selected input port (MMM) into the accumulator.
OUT	(6)	0 1	R R M	M M 1	Write the content of the accumulator into the selected output port (RRMMM, RR ≠ 00).

MACHINE INSTRUCTION

MNEMONIC	MINIMUM STATES REQUIRED	$D_7 D_6$	$D_5 D_4 D_3$	$D_2 D_1 D_0$	DESCRIPTION OF OPERATION
HLT	(4)	0 0	0 0 0	0 0 X	Enter the STOPPED state and remain there until interrupted.
HLT	(4)	1 1	1 1 1	1 1 1	Enter the STOPPED state and remain there until interrupted.

NOTES:

(1) SSS = Source Index Register ⎤ These registers, r_i, are designated A(accumulator–000),
DDD = Destination Index Register ⎦ B(001), C(010), D(011), E(100), H(101), L(110).

(2) Memory registers are addressed by the contents of registers H & L.

(3) Additional bytes of instruction are designated by BBBBBBBB.

(4) X = "Don't Care".

(5) Flag flip-flops are defined by C_4C_3: carry (00-overflow or underflow), zero (01-result is zero), sign (10-MSB of result is "1"), parity (11-parity is even).

C1702A/S714 2048-bit pROM's, a 3-ROM set for bootstrap loading and pROM control, and an 8-ROM set containing the assembler program (also available in paper tape). Excluding the previously mentioned TTY and the unmentioned but obvious power supply, cables and ultraviolet pROM eraser, the bill for all this comes to $2760, according to my price list. You've come a long way from an 8008-1 microprocessor at a one-off price of $180 to a prototyping system that is sure to come in at over $3000, once everything is accounted for. But that's what it takes and if you're serious about this business, that's the least you'll have to pay.

For anyone who expects to be doing a great deal of programming development of MCS-8 based systems, the Intellec 8 represents a more convenient choice than the minimum system described. But for the purpose of our software discussion, it will be assumed that the user has at least that minimum system available to get hands-on experience.

Back to the chip

Now that you've seen what sort of system can be, and in fact, must be built around the 8008 chip to make it useable, let's go back and look at the chip itself.

The 8008-1 executes nonmemory referencing instructions in 12.5 µsec when operating from an 800 kHz clock (20 µsec for the 8008 with a 500 kHz clock). There are 48 variable byte instructions including data manipulation, binary arithmetic and jump to subroutine. Most instructions are coded in one byte (8 bits), but data immediate instructions use two bytes, and jump instructions need three. There is one 8-bit accumulator, seven 8-bit general registers, four condition flags, eight 14-bit address stack registers, eight 8-bit input ports and 24 8-bit output ports. It interfaces with

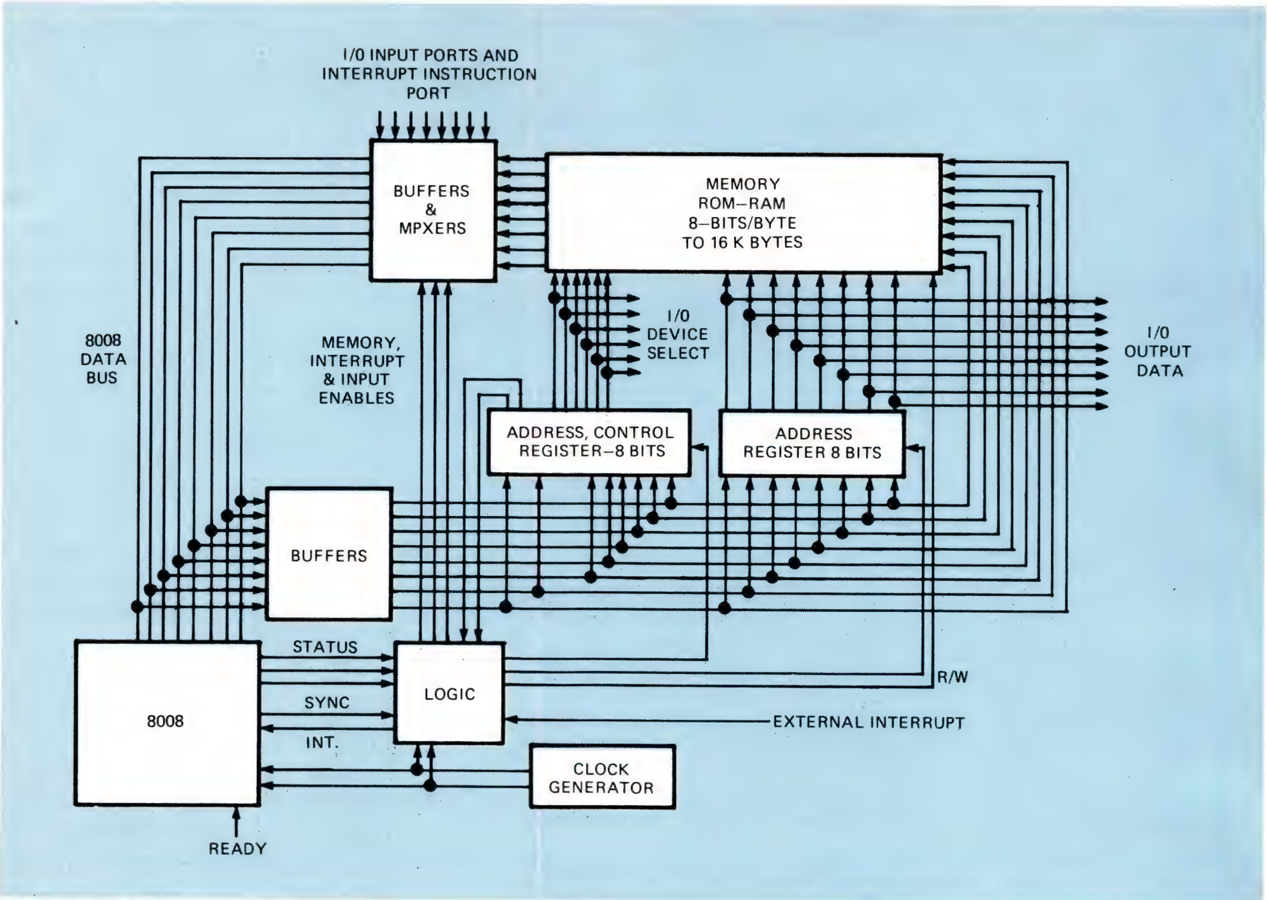


Fig. 3—MCS-8 basic system shows the external electronics that must be added to the 8008 processor to make it a computer.

ROM's, RAM's, pROM's and shift registers to form a general-purpose computer. The 8008 is an interruptable, 2's-complement processor that can directly address up to 16k bytes of memory (any mix of ROM, RAM, pROM or SR). That's better than many mini's and is a direct consequence of the 14-bit addressing used on the chip.

The instruction set

Table 1 shows all the instructions available to the MCS-8 programmer. The first column of the table gives the assembly language mnemonic for each instruction. The second column is concerned with the number of timing states that it takes to carry out the instruction. Typically a machine cycle consists of five states (**Fig. 2**). During a machine cycle, states T_1 and T_2 are used for sending an address to memory; T_3 is for instruction or data fetch; and the two states, T_4 and T_5, are used for execution of the instruction. As can be seen from **Table 1**, as many as 11 states are required for some instructions.

The instruction code column of **Table 1** indicates the machine code and number of bytes (1, 2 or 3) required to execute an instruction. Finally, the last column describes the operation of each instruction.

There are five basic types of instructions: index register, accumulator group, program counter and stack control, input/output and machine instructions.

Index register instructions are used to load or move data between index registers and memory registers, load processor or memory, and increment and decrement the index register.

Accumulator group instructions are concerned with things done to or with the single 8-bit accumulator. They can be classified in several ways: The ALU index register operations are carried out between the accumulator and the content of one of the index registers (SSS = 000 through SSS = 110). ALU operations with memory are arithmetic and logical operations carried out between the accumulator and the byte of data addressed by the contents of registers H and L (memory register). ALU immediate instructions carry out arithmetic and logical operations between the accumulator and the byte of data immediately following the instruction. Finally, rotate instructions, the last of the accumulator group, shift accumulator contents left or right.

Program counter and stack control instructions are of four types. Jump allows the normal flow of the program to be altered by jumping to an address specified by byte two and three of an instruction. Call allows subroutines to be called and nested up to seven levels. Return instructions are used to exit from a subroutine and pop-up the pushdown stack one level. Restart acts as a 1-byte call on eight specified locations of page zero (the first 256 instruction words).

Input/output instructions are self explanatory and machine instructions are merely a halt command to the processor.

Assembling programs

Programs are originally written in symbolic assembly language. This is put into punched-tape format on the teletype™. The hardware assembler, mentioned previously, translates that tape into an octal representation of the MCS-8 machine language. An auxilliary program then translates this octal object code into the "BNPF" format suitable for bootstrap loading.

"BNPF" deserves a little discussion since it is not a common programming format. It's an Intel oddity that was developed because of their particular requirements to transmit programs over teletype. If binary is used, all transmissions would use the characters ZERO and ONE. But in ASCII code, there is only a 1-bit difference between the codes for **0** and **1**. Thus, any glitch in the right spot can make a **0** print as a **1** and vice versa. If instead, a **P** is used for a **1** and an **N** for a **0**, then noise or other transmitted errors are obvious. For every eight binary characters represented by N's and P's, there are two additional characters—a **B** for begin and an **F** for finish. So BNPF code looks like this: BNNNPPNPNF BNPNNPNNF.

That's an odd arrangement for programmers, but for a hardware designer taking his first fling at programming, it's no stranger than the rest of this. But there's more to this than BNPF. Let's take a look at the steps involved in developing a program.

Practice makes near-perfect

The only way to really learn to write MCS-8 programs is to take the instruction set (**Table 1**) and start writing programs around it. Of course, that means you should have all the equipment previously mentioned to debug the programs you've written. But even without the necessary equipment (SIM8 or Intellec 8), you can practice writing programs in the MCS-8 assembly language.

Except that the mnemonics are somewhat different, assembly language does not appear to be much different than that discussed in Part I of this series. Machine language, because of its one, two or three 8-bit byte organization, is more unusual. Assembly language coding of a sample program is shown in the following example along with its binary machine language representation:

Assembly Language

```
1) START HLT
2)       LBI  001   Load Index register B with 001
3)       LAI  000   Load Index register A with 000
4) L1    OUT  010   AC contents to output port 010
5)       ADB        Add Index register B to AC
6)       LCA        Load C from A
7) L2    INP  001   Read input port 001 into AC
8)       RRC        Rotate AC contents right
9)       JFC  L2    Jump to L2 if false
10)      LAC        Load A from C
11)      JMP  L1    Unconditional jump to L1
         END
```

Machine Language (same program)

```
1)  00000000
2)  00001110  00000001
3)  00000110  00000000
4)  01010001
5)  10000001
6)  11010000
7)  01000011
8)  00001010
9)  01000000  00001000  00001010
10) 11000010
11) 01000100
```

This simple program is only intended to show the sort of things that can be done with the instruction set. Most programs will be considerably longer and more complex, as shown from this assembly language program provided by Intel Corp:

```
BEGIN LAI 1                 SUPPRESS TTY
      OUT 12B               OUTPUT 2
      XRA                   CLEAR AC
      OUT 13B               OUTPUT 3 - TAPE R
EADER CONTROL
      CAL TAPE              CALL FOR TAPE REA
DER CONT. RT.
      JMP BEGIN
TAPE  LAI 1                 TAPE READER ENABL
E CODE
      OUT 13B               OUTPUT 3 - ENABLE
 TAPE READER
      CAL TTYD1             TAPE READER CONTR
OL DELAY
TTY   HLT                   WAIT FOR TTY STAR
T PULSE
      CAL TTYD2             TTY DELAY - 4.468
 MSEC.
      XRA                   TAPE READER DISAB
LE CODE
```

```
         OUT 13B         OUTPUT 3, DISABLE
  TAPE READER
         INP OB          INPUT 0, READ STA
RT PULSE
         LCI 255         COMPLEMENT TTY ST
ART PULSE
         XRC             EXCLUSIVE-OR REC.
  C
         OUT 12B         OUTPUT 2, OUTPUT
START PULSE
         LEI 248         TTY DATA SAMPLING
  COUNTER
TTYIN    CAL TTYD1       TTY DELAY - 9.012
  MSEC.
         INP OB          READ TTY DATA INP
UT
         LCI 255         COMPLEMENT TTY DA
TA
         XRC
         OUT 12B         OUTPUT 2, TTY DAT
A OUT
         RAR             STORE TTY DATA
         LAB             LOAD TTY DATA TO
REC. B
         RAR
         LBA             LOAD AC TO REC. B
         INE             E = E + 1
         JFZ TTYIN       JUMP IF ZERO F/F
IS NOT SET
         LAB             LOAD REC. B TO AC
         OUT 11B         OUTPUT 1, TTY CHA
RACTER
         SUI 128         REMOVE PARITY BIT
         LBA             STORE TTY INPUT D
ATA
         CAL TTYD1
         LAI 1
         OUT 12B         SUPPRESS TTY
         RET
TTYD1    LDI 115         9.012 MSEC DELAY
ST       IND             D - D + 1
         JFZ ST
         RET
TTYD2    LDI 186         4.468 MSEC DELAY

ST2      IND             D = D + 1
         JFZ ST2
         RET
         END
```

One needn't write programs of that length to gain programming experience, however. Most long programs are really a combination of much smaller routines, and the program shown here is no exception. Practicing with small programs that do basic things is the best way to gain experience. Once that's done, it's a simple matter to string the basic routines together. Then, a complete system is required to check the program for errors as written and, later, to debug it. To do this requires some understanding of the techniques involved; that is, the actual manipulation of programs, tapes, hardware, etc. required to generate an object tape or BNPF tape.

Putting it all together

The first step, obviously, is to write the program in symbolic assembly language, as has been discussed. Next, a source tape is punched on the ASR-33. Then the SIM8 must be prepared. This requires loading of the assembler ROM's, presetting the interrupt instruction and bootstrap loading of the last page of the assembler into read/write memory. Now complete pass one. This is done by placing the source tape into the reader and giving the assemble command. (ASSEMBLE: origin. Origin is any octal value from 000:000 to 777:777, depending on where the program is to start.) The pass one listing is done by the assembler which reads the source tape, prompts all assembly lines, ignores comments and generates a symbol table.

Pass two requires a reread of the source tape. It is initiated by a LOAD or LIST command. (Load command puts the object code into memory, list does not.) If the paper tape punch is turned on at that time, an octal version of the object code is generated.

Assuming there have been no errors in assembly (or the source tape has been edited, corrected and a new object tape generated), you may elect to put the program into memory. If you wish to program pROM's or do bootstrap loading, you must convert the object tape into a BNPF tape. This is done by loading the BNPF program (Intel Tape A0849), loading the object tape and executing the BNPF tape generator program to produce a BNPF output tape and TTY readout.

How to end tedium

If all this seems time-consuming and tedious—it is! Larger computer systems use FORTRAN, COBAL or BASIC or WHATEVER higher level language compilers to generate many machine instructions from a few commands. But there are inherent inefficiencies in such an approach. Too much machine code may be generated, and in a small system, that just fills up memory and bogs down the processor with unnecessary steps.

There is a higher level language available for the MCS-8. It is optimized so that with a little practice in its use, programs can be written with only a slight loss of efficiency. That language is called PL/M. It can be run on any large-scale computer. The PL/M compiler, cross assembler and simulator may be procured directly from Intel or can be accessed through a number of national computer time-sharing services. The next article in this series will concentrate on PL/M. □

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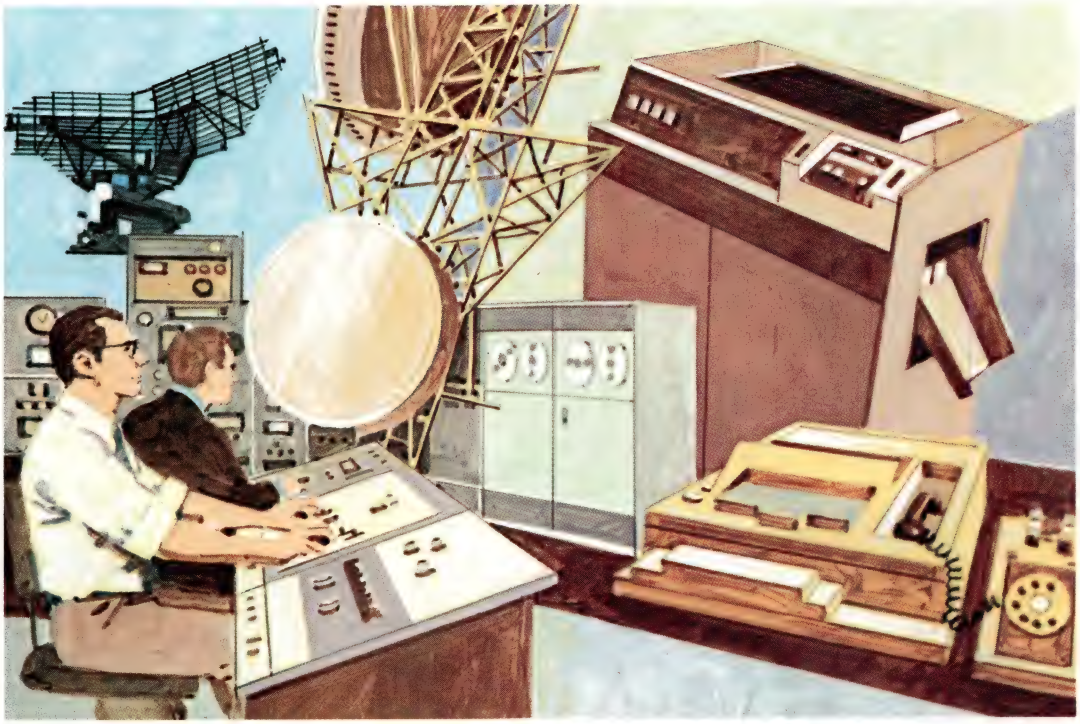

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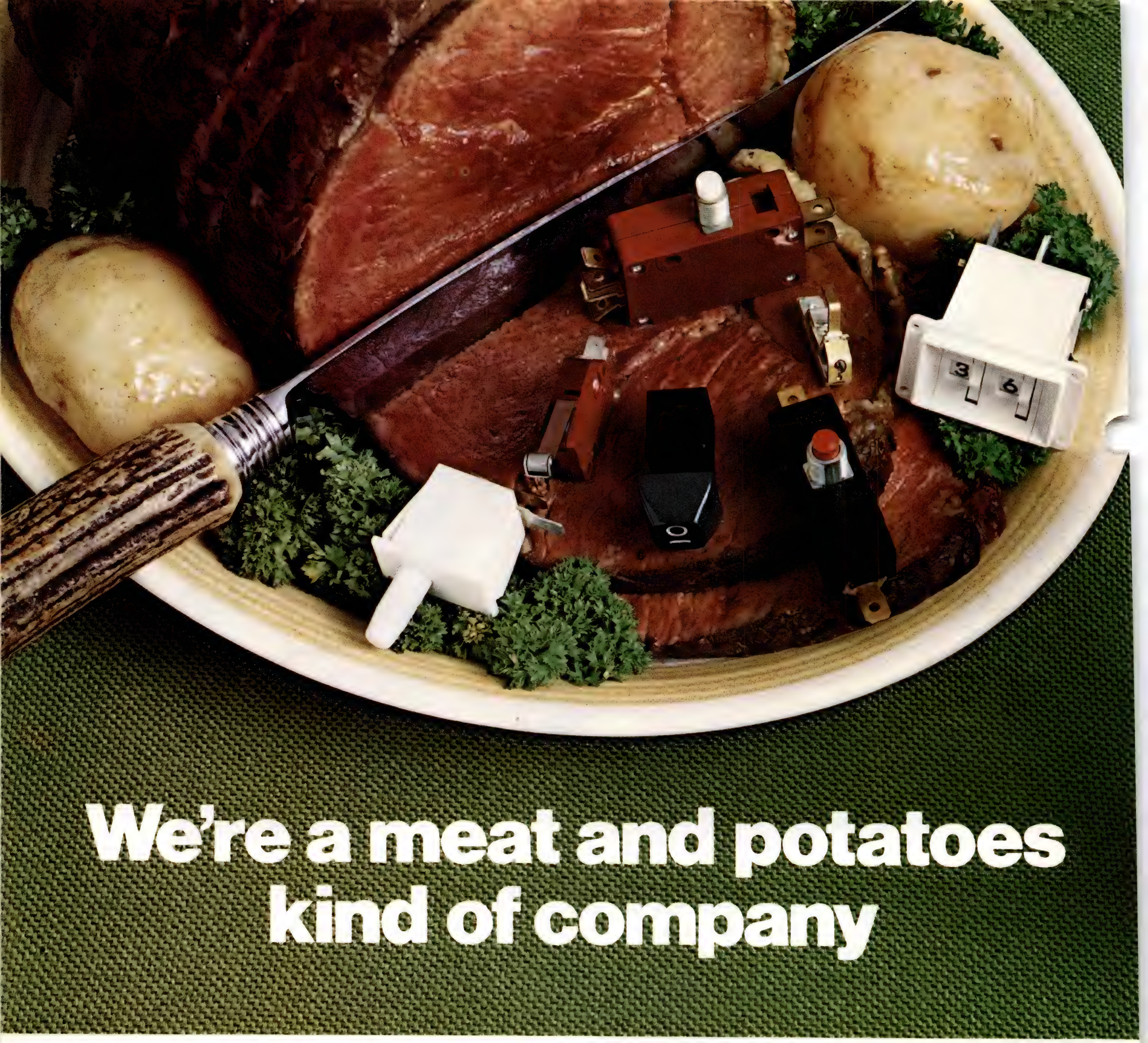

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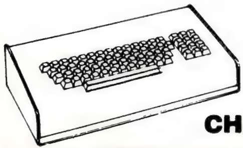

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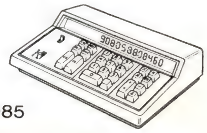


ELECTRONIC DESK TOP CALCULATORS

Do you have what it takes to be an EFFECTIVE engineer?

Ineffective engineering represents a horrendous and needless waste of valuable talent. Here is how to increase your effectiveness.

Thomas T. Samaras, Hoffman Electronics Corp.

Many engineers are ineffective at their jobs. Instead of being a driving influence in their companies, they are influenced and driven. This need not, and should not, be the case. Any individual who has the intelligence and drive to obtain an EE degree must have something on the ball. But all is wasted unless he learns to be effective on the job.

What is an effective engineer? To me, an effective engineer is one who does the complete, correct job, within a reasonable schedule, and within available funds. Is doing a good design job the prime factor? Not necessarily. From the point of view of industry, completing your design on time and within budget are equally important. Delays in designing and marketing a product mean sales and revenue lost to competitors, or, in the worst case, it can mean creating a product after the need for it has disappeared. Alternatively, design, development and production costs, higher than target, may mean that the product cannot be profitably marketed at competitive prices, so sales suffer. Let's not forget that many businesses fail each year for just such reasons.

Learning a lesson the hard way

A good example of what can happen when a time schedule is not met occurred recently in California. A unique approach to detecting and analyzing harmful products in the atmosphere was the basis for the formation of a small company by a group of engineers and businessmen. Having limited resources, they established a time table for introducing their new equipment on the market. This schedule was based both on their estimate of how long it would take to solve several key technical problems and on the funds available to keep the company solvent. Market introduction for the equipment was set to coincide with the issue of stock. Thus, additional money could be obtained to enable the company to go into production and successfully market

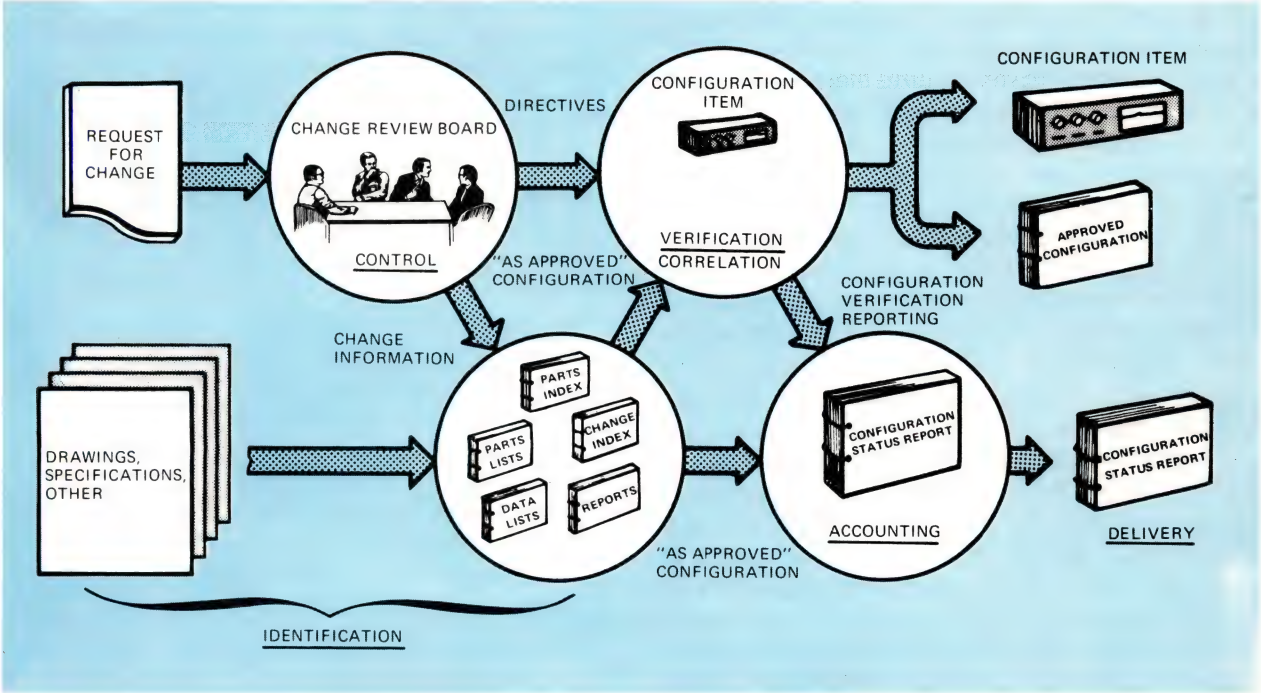


Fig. 1—Key elements of configuration management are indicated in this flow chart.[3]

their unique product.

Unfortunately, the prototype was not fully operational when the stock offering was made.

Investors were therefore unwilling to pay the price per share needed to get the company into production. As a result, staff and operational costs had to be reduced to a minimum—just enough to get the equipment working. The company tottered near the brink of bankruptcy—saved only by the introduction of additional capital by one of the original investors. After several more months the company had almost solved its technical problems, but was still in deep financial trouble. Effective engineering would have prevented these problems.

Besides the marketing disadvantages of high costs and late completion of work, ineffective engineering also causes problems in the technical area. Lower profits mean less money for R&D, laboratory equipment, new facilities and pay raises, while schedule slippages delay new design starts. Fresh design challenges are thus postponed, while old projects drag on and on.

Since ineffective engineering inevitably produces undesirable consequences, let's take a positive approach. Here are the five major requirements which an engineer should master in order to be effective: the technical basics, creativity, management ability, human relations skills and configuration control.

It may sound elementary, but...

Knowledge of design techniques and materials/components is a necessary factor for an effective engineer. Basic design techniques, including network and matrix analysis, Fourier and Laplace transforms and tradeoff studies are, of course, essential in developing electronic circuits and systems. Familiarity with various types of circuits is also important; e.g., filters, impedance matching networks, oscillators, amplifiers (pulse, IF, RF, operational and dc), etc.

Most engineers acquire substantial knowledge and proficiency in these techniques or circuits from their formal engineering courses. However, an engineer gradually becomes rusty in their use if he doesn't work with them regularly. This is natural, and can be avoided only by periodic reviews. Are you currently proficient, or stale?

In addition to basic design techniques, new methods using special devices are continuously being developed to help engineers make faster and more accurate designs. Interactive CRT consoles and computers enable engineers to explore many more design options or approaches in much less time. In some cases, productivity increases up to 48 times. Automated drafting systems help designers make more precise layouts and artwork for printed wiring boards at a fraction of the time used with traditional methods. Computers can perform modelling, simulation, and circuit synthesis and analysis. They handle, in minutes, complex calculations that would normally take hours or days to do.

Finding the information

Where do you find the information you need to be an effective engineer? Of course, your personal library of technical books and articles is a key source of information. But, as I'm sure you know, you can't always find what you need there. Fortunately, other information sources, including the following, often prove to be helpful.

Library/information center: Company and local libraries often contain the information you need. If they don't have it, the library or information-center staff often can help you find what you need, including abstracts of books, articles and reports.

Technical information sources: Several Government technical information centers can be tapped for new developments or research in your area of interest. Reports are supplied at nominal charges by the National Technical Information Service, NASA, Department of Commerce and Defense Documentation Center. Trade and industry associations are also excellent sources of technical information. For instance, the American National Standards Institute (ANSI) offers over 4000 standards as guides to industry.

Friends and associates: Don't overlook friends and associates when you need information. They may have direct experience or information files that can save you hours, days or even years of work. Most good engineers appreciate the opportunity to help an associate—providing, of course, that the service is not abused.

Experts in field: Contact with experts in the field, even if working at another company, can be an extremely valuable source of information. Lists of names of people working in specific fields, where and under whose support, can be obtained from the Smithsonian Science Information Exchange (SSIE). This exchange supplies data on current research in all areas of science and engineering.

Technical book publishers: Many technical book publishers have catalogs on technical and reference books that may be useful.

Are you familiar with, and proficient in, the use of such modern engineering tools? To be most effective, you must be. Take advantage of every opportunity to learn.

Know your components and materials

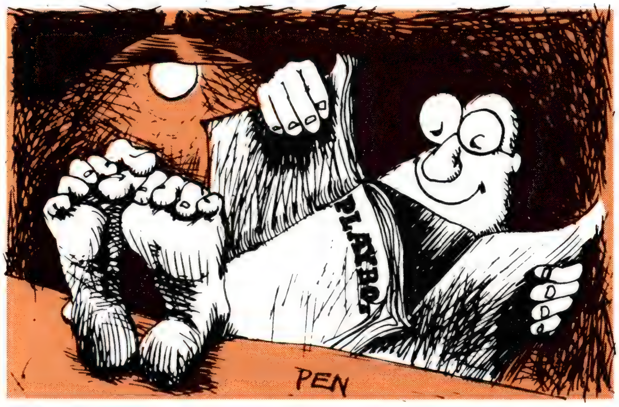
Knowlege of components and materials is a key ingredient in improving old products or developing state-of-the-art devices. This dynamic area requires constant review if an engineer is to be effective. Engineers should be ever alert to new developments which produce novel solutions to old problems.

How do you keep current on new developments? Read trade journals regularly. Attend exhibits and seminars. But do not trust the valuable information you gather to your memory alone. A more formal and systematic approach is needed. For example, a separate notebook or file of new components and materials should be maintained. Periodically review it to refresh your memory, discarding obsolete material.

Broaden your outlook

Obviously, a good understanding of the basic disciplines related to your area of specialization is essential to being an effective engineer. However, one should not forget that a broad knowledge of other, somewhat unrelated, disciplines can also be valuable. For example, I once took a night course in thermodynamics. At the time I didn't think it was worth much to an electronics engineer, but I was somewhat interested in the subject. One concept, the Second Law of Thermodynamics, stuck with me through the years. Then, somewhat to my surprise, I was able to apply this law to a discussion of organizational behavior.[1] You just never know what knowledge might eventually be useful.

A breadth of knowledge, if not acquired in your formal education, can also be self-taught. Read basic textbooks, concentrating on subjects which either interest you or which you feel might someday be useful. Remember that in-depth knowledge isn't required unless you have a specific problem to solve. A good understanding of fundamentals will be adequate for most situations, since it will enable you to recognize, in some detail, where you need help.



"...concentrate on subjects which either interest you or which you feel might someday be useful. Remember that in-depth knowledge isn't required unless you have a specific problem to solve."

Speaking of knowledge, we sometimes tend to forget that it can be either theoretical or practical. The effective engineer gets things done, so he recognizes the value of practical knowledge. Specifically, he should know how the equipment he is designing is assembled, documented, tested and operated.

For example, a knowledge that the production environment requires rapid, simple operations can provide many benefits. It will help you avoid designing unnecessary precision into your product. That is, you won't design a frame for holding pc boards that requires an assembler to follow a very careful and slow alignment procedure before he can slide the board into its frame. Such awareness will also reduce the cost of manufacturing the frame. It will help maintenance people by reducing the difficulty in removing and replacing defective boards. It will also minimize equipment down time and repair costs, which is a valuable feature for the end-user.

To acquire a practical knowledge of good equipment design, talk to production personnel, quality-control inspectors, test engineers and, if possible, customers themselves. Effective engineers, knowing what troubles are usually experienced with new products, plan their designs to avoid problems, not create them.

Consider these aspects of creativity

Effective engineers possess a measure of creativity. By creativity, I mean the ability to combine various elements in unique ways to solve a problem or develop a new product. However, this creative ability often must be coupled to other objectives before it can be valuable. Such objectives include creating new, useful products or finding ways to reduce the costs and improve the performance and reliability of existing products. Creativity can also be applied to nonhardware areas, such as developing new procedures or organizational techniques to improve efficiency or reduce schedule times.

As an example of a creative design achievement, I recall a system which was using two similar, but totally independent, amplifier circuits to perform two different functions. A creative engineer, recognizing that the two amplifiers were never called upon to perform their functions at the same time, reduced the two circuits to one. Fewer parts, smaller space requirements and higher reliability were the results of his creativity.

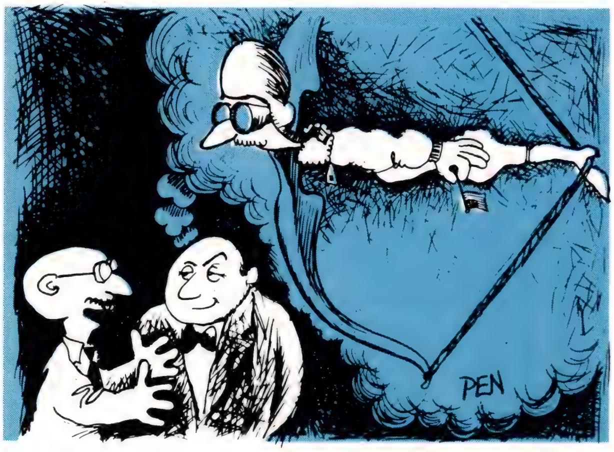
Creativity in a nonhardware area can also readily be described. In this case, an inefficient personnel mix existed in a drawing and change-control group. The chief engineer, recognizing the problem, applied his creativity to reorganize the department. The key to his solution was to assign the right person to each job, being careful to avoid job descriptions which would produce an overqualified staff. The mix of personnel, before and after, was as follows.

Before	After
Supervisor	Supervisor
Supervisor	Design-draftsman
Design Checker	Sr. Draftsman
Design Draftsman	Draftsman
Sr. Draftsman	Sr. Clerk
Sr. Clerk	Clerk
Clerk	Clerk

As you can see, the quantity of people remained the same. Yet the final optimum mix produced significant benefits. The group's overall performance was much improved and a cost savings of $10,000 a year was realized. Overqualified people, moved into jobs that could better use their abilities, were well satisfied with their newly challenging positions.

Can creative ability be developed? I believe it can. Everyone with normal intelligence can be creative—if he is willing to work at it. The principal ingredients to creative accomplishments are motivation and the acquisition of a sound body of knowledge. Other factors include an active, independent and curious mind, plus the flexibility and readiness to examine new approaches even if out of step with most current beliefs.

For example, a few years ago I heard an engineer tell a physicist that he thought man would find a way to go faster than the speed of light. The derisive smile on the physicist's face could have turned off a sensitive person, but that engineer had the self-confidence to stick to his creative viewpoint. He deserved respect, not because he could prove his statement, but because he had the imagination to see beyond the narrow confines of established knowledge.



"...a few years ago I heard an engineer tell a physicist that he thought man would find a way to go faster than the speed of light."

Do you organize and control?

Management ability often makes the difference between a successful engineer and a failure. By management ability, I don't mean the supervision of many people, but rather the organization and control of your area of responsibility. This ability is necessary because an engineer rarely works in a secluded laboratory. Instead, he must interface with, and properly coordinate the activities of, such functional groups as purchasing, drafting, quality assurance, reliability, standards, manufacturing and testing. The effective engineer recognizes this fact and manages his activities according to a basic procedure, which he modifies as appropriate to each project undertaken. The following procedure is recommended.

1. Identify your objectives and tasks in as specific and detailed a manner as you can.
2. Identify who you will need help from and when. Let him know what you are doing before you really need him. Let him know what your key problems and constraints are. Remember, he may save you a lot of lost time and problems because of his experience and specialized know-how. Two (or more) heads are usually (not just often) better than one.
3. Maintain good communication networks with those above as well as below you. Experienced managers and engineers often fail to explain what they really need from others and to define what constraints apply to their associates' work. As a result, people go off in many different directions and much effort and time are wasted. To avoid such problems, document clearly and completely what your boss wants you to accomplish and what you want from others working for or with you. Ensure that everybody correctly understands what has been written.
4. Keep complete, accurate (and readable) reports, notebooks and records. They are very important. Without them, modern industry would literally come to a stop.

Improve your human relations skills

This section is not intended to be an insult to your intelligence! Rather, it is included because the ability to work well with people and to get them to cooperate with you is a critical part of

"Maintain good communication networks with those above you as well as below you."

being an effective engineer. Very often, the brilliant student turns out to be a mediocre engineer because he doesn't know how to treat people, to win their respect, and to focus efforts into the right channels. Does this mean that to be effective you have to agree with everyone or that you have to be liked by everyone? Certainly not. It just means that you must be able to interface well on a personal level.

How do you improve human relation skills? Although reading text books on human psychology may help, reading good books, such as "War and Peace," can enhance an engineer's understanding of other people's feelings, needs, fears and problems. The object: to develop a sensitivity to, and an empathy for, coworkers.

Here are some additional guidelines to follow if you want to improve your human relations skills.

1. Be aware that the other person has feelings, needs, insecurities and problems just as you do.
2. Account for differences—culture, education, experience and physical characteristics.
3. Don't mistake your specialized knowledge for overall superiority. An associate who knows less about microwaves but knows more about audio electronics, human relations, business or management may well be superior in his own right.
4. Present criticism only when it is warranted, and then be careful to do so constructively and unemotionally. When possible, balance criticism with praise.
5. Be polite and considerate. "Thank you" and "please" help maintain good human relations. The little things in life are important.
6. Be fair, impartial and honest. Personal integrity breeds respect.
7. Give people credit when they deserve it. Positive reinforcement is generally more effective than criticism.
8. When in doubt, apply the "Golden Rule."

There's no substitute for hard work

Hard work is another quality of an effective engineer. This means hard work both on the job and at home. Rare is the engineer who can be effective at work without some self-study and home work. Electronic technology changes so constantly and rapidly, and the body of knowledge it encompasses is so great, that it is vital to keep acquiring knowledge. Read trade journals, text books and professional books. Attend seminars, join technical societies and take post-graduate courses. But remember, just a light reading of journals, magazines and books will not suffice. Instead, hard study and a concentrated effort to learn are needed.

A systematic method of collecting and analyzing new information is the best study procedure for most people. I recommend that each important article or fact be properly identified (in case it is necessary to go back to the original magazine or book) and inserted in a well-organized notebook. All information in this notebook should then be periodically reviewed and studied. While everything can't be memorized, important facts ingrained in your mind are more readily applied to work and can help make you more efficient.

Never take anything for granted

This should be a cardinal rule for the effective engineer. I don't mean you have to do everything yourself—only that when you ask someone to do something by a certain date, don't wait till then to find out how it's going. It may not be going at all!

Failure of others to respond to your request for help isn't usually due to laziness. People often have many things to do. They may interpret from your manner that your task isn't urgent and therefore work on projects that seem more pressing. Of course, you can't solve the problem by telling people that everything you need is hot. But if you specify a date for completion of your work and give them a fair amount of time to do it, then you have a legitimate gripe when they aren't on schedule. Unfortunately, even when something is hot, people may not respond unless you follow-up on it. Whenever possible, do your own leg-work. Personal contact has many, many benefits.

For example, I recently had a critical engineering order to release before some expensive equipment could be shipped to a customer. I notified the first person in the processing loop that the order had to be released that same day. However, in following it up, I found that each person I contacted about pushing this order through failed to emphasize its urgency to the next person in the loop. The result? The processing floundered until I personally explained to each individual the reason why the immediate release was important.

Such problems occur all the time in industry. Every reader could cite some excellent examples, I'm sure. Even managers and engineers who should know better fail to follow-up on work assigned to others. Consequences range from minor inconveniences to expensive delays. But the effective engineer avoids them by anticipating possible problems and "heading them off at the pass."

Use configuration management

Another approach to effective engineering is configuration management.[2] This relatively new discipline involves a systematic approach to ensure that a product meets its specifications or requirements and is adequately documented. Isn't this an obvious and natural byproduct of the engineer's efforts? Unfortunately, the answer is no.

A good typical example of an all-too-familiar situation occurred when a large company was in the throes of developing the first model of a sophisticated electromechanical system. Management and customer pressure was intense to get the system working so production could begin. Engineering, working feverishly to obtain the required performance, made on-the-spot design and hardware changes. Finally, success was achieved. The customer accepted the first system as meeting his needs. But, all was not well. In the haste to get the system working, few engineers documented all the changes made. As a result, thousands of man-hours were wasted trying to correct the documentation by carefully examining the hardware for discrepancies.

Effective engineers recognize their vulnerability under such conditions of stress. They insist that special precautions be taken to protect themselves and the company. What could they have done in this case? One solution would have been to ask for assistants to record and identify the exact nature of all changes made. Such extra help would not have been an extra overhead burden. Quite the contrary, it would have saved much time and money and simultaneously avoided considerable customer dissatisfaction.

Configuration problems are not limited to large systems. Control can also be lost with small units. For example, at a small company, a technician was making simple on-the-spot corrective changes to hardware without telling anyone. As new units were continuously built with the same problem, this technician had to shorten a metal bracket over and over again because hundreds of the wrong-size brackets were ordered using the uncorrected drawing. Had the technician told the responsible engineer earlier, the drawing could have been changed, the right brackets ordered, and unnecessary costs and delays avoided.

"Configuration problems are not limited to large systems. Control can also be lost with small units."

Such experiences led to the development of configuration management, which consists of four basic parts (**Fig. 1**):

1. Identification of the design on paper (drawings, parts lists, test procedures, specifications, etc.).
2. Control of changes to officially-approved documents.
3. Keeping records of changes to approved documents and their implementation in delivered hardware.
4. Verification of change incorporation into hardware.

Perhaps one of the most important activities in configuration management is evaluation of the impact of a change. Even minor modifications to a design released to production can ramify until a whole program is jeopardized. For example, suppose an engineer finds, after he has released a drawing, that a new component will do a better job or eliminate several other expensive parts in his design. From a technical viewpoint, if he changes his drawing he is probably perfectly correct. But, on the other hand, it is quite possible that his actions could produce disastrous results such as these:

1. The new parts, while advertised as available in one month, actually arrive at the plant three months after they were ordered.
2. Because the new part was just developed by the supplier, a high number of defective parts are found, so QC returns the entire lot to the supplier. Additional work and more

delays are created.

3. Later, after installation, parts which were apparently good fail to perform properly after assembly and checkout of the system. Additional costly delays thus occur.
4. When the company fails to deliver on time, a daily penalty is incurred until shipment is made. Profits plummet.

The effective engineer recognizes and fully evaluates all ramifications of all the design changes he makes. He considers all areas likely to be affected by a change, including test and training equipment, manuals, spare parts, gages and fixtures, and procedures. Moreover, he disciplines himself to communicate with appropriate parties whenever a change may even remotely affect another product or another schedule, even if this means setting up or participating in a change review board. He recognizes his responsibilities and fulfills his obligations.

Putting it all together

Just the fact that you read this article to this point proves that you have at least some of the basic traits of an effective engineer. If you now follow through, by applying the principles which have been discussed, you will find that the benefits far exceed the efforts required. I wish you well. ☐

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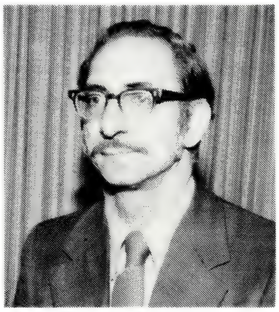
Author's biography



Thomas Samaras is manager of design support at Hoffman Electronics Corp., where he is responsible for drafting, design checking, data control and configuration management. Tom received his BS in engineering from California Sate University at Los Angeles and now lives in Claremont, CA. A member of Tau Beta Pi, he is also presently the administrative vice president of Toastmaster's Club 12.

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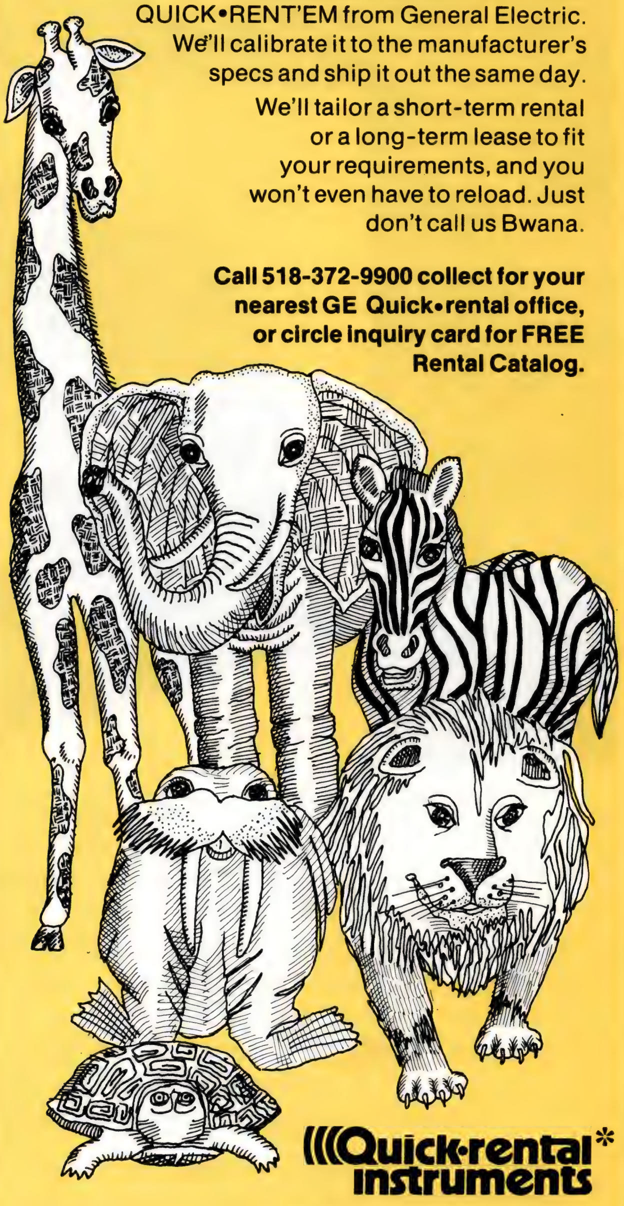

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Circle No. 38

Low-power logic: How low do users want it to go—Part 2

Designers discuss their uses of low-power logic, and detail what they'd like to see in the future.

EDN's latest Roundtable brought together six designers from both IC manufacturing and user companies. The comments of the IC designers were presented in the May 20th issue of EDN, and here are the comments from IC users.

Ultra-low not needed for calculators

Speaking first was Tom Whitney of Hewlett-Packard:

"I think the question facing the system designer is how much low power do you really need. This involves examining your product goals very critically because it is an important decision to be fixed.

"In the HP-35 and in pocket calculators in general, the design proceeds in a reverse order in some ways. The question for us on power was set by the size of the product which we wished to obtain.

"As the story goes, the size of the HP-35 was set by Bill Hewlett's shirt pocket, which we decided was standard size. We had to fit the HP-35 into that shirt pocket. With that volume constraint, we then proceeded to select the battery that we had room for. We picked three double-A size nickel-cadmium batteries at about 500 mA hours of energy each. This then set the amount of energy which we had available to us. The question now was: Is it possible to implement the product with this amount of available power?

"Another parameter which had to be selected was the operating time of the calculator, and we decided upon four hours. We thought that this would provide a standard working day for a typical person with a conservative specification. I think if you turn the calculator off when you're not actually using it, the four hours are a good average.

"Working backwards from this, we knew the algorithms that we had to implement. We started with our system design and specified a 200 kHz clock rate in order to be able to execute the algorithms in less than one second, which was a time constraint. At this point we had finished the system design and had, basically, a 3-chip system.

"We went out to a variety of vendors asking for quotations on building this system. We did not specify which process the vendor was to use in making this quotation, rather we provided the voltage specifications, +6 and −12 supply voltages, the 200 kHz clock rate and the 3-chip system. We received data on seven quotes which we solicited.

"Essentially, four of the quotations were valid; that is, from people who felt that they could meet our specifications. This was in the spring of 1971. One of those four proposed CMOS implementation and the others proposed various forms of PMOS. We selected two vendors, both of whom used ion-implanted PMOS. We did not select the CMOS process which, as it turns out, was sort of an overkill in terms of power.

"We felt that four hours operating time was adequate. We didn't really need eight hours, and the cost would have been greater. The circuits would have been larger at that time to implement the same system using CMOS, so we selected the two vendors using ion-implanted PMOS. The power specification on the circuit we had selected was set at 200 mW. In both cases, the vendors provided parts which were better than our requirements.

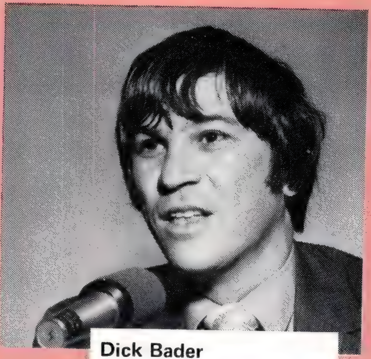
"We found the circuits consumed 100 to 150 mW, so I guess what I'm saying is that for our requirements PMOS was an adequate implementation. Since that time, we have come out with additional products which are more complex than the HP-35 and in which we needed additional read-only-memory. In most cases we wished we had additional operating speed in the system.

◄ Circle No. 71

Participants in the EDN Designers' Roundtable on Low-power logic

Bill Furlow
EDN Magazine

Tom Whitney
Hewlett-Packard


Dick Bader
Integrated Microsystems

Dick Hall
Systron Donner

This comes about because the algorithms now being implemented in some of our newer calculators are very complex. For instance, on the HP-80 calculator when we solved for the interest rate in a financial type problem, interest appears implicitly in the equation. That is, you have to do a recursive procedure to solve for the interest rate. And essentially it's a trial and error solution which you iterate many, many times.

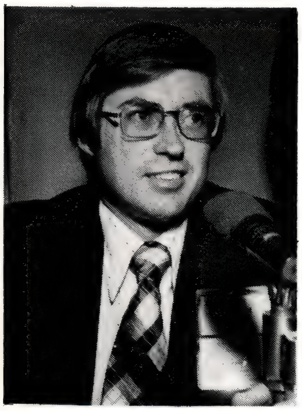
"Our product is a hand-held calculator and, therefore, involves a human interface. We generally assume with human interface type systems that speed is not a problem, but this is changing in terms of the complexity of the type of problems that we're solving. And we wish now that we had a faster processor.

"The increased sophistication comes from additional use of ROM. What we require are techniques for implementing ROM with very little power, and what we have done now is gone back and designed a new ROM circuit which has 4× the bits of our original ROM and only takes about twice the power. Therefore, we are able to increase the ROM in our products without a proportional increase in power requirements. The HP-45 calculator is much more complex than the HP-35. However, we still specify the same four hours of operating time, with the same batteries. That's because the power consumed by the ROM is such a small part of the total power consumption of the calculator.

"What do we see as our requirements for the future? As I mentioned, even for hand-held calculators we're going to require higher operating speeds. In fact, I think we would like to see a higher clock rate. Instead of 200 kHz, we'd like a clock rate on the order of 1 MHz.

"We are going to continue to require higher densities in our circuits. Hopefully, lower power requirements will be seen, although this is not the overriding factor. As we said, we feel that four hours of operating time is adequate for this type of calculator. Our customers have not complained about it. If they do, we've designed a battery holder in which you can remotely charge your nickel cadmium batteries. The batteries can be taken out of the calculator so that you don't have to tie up your calculator recharging it. This has been a very popular solution to the problem of operating time. You can always carry an extra battery pack with you.

"The other area that is going to be a requirement is lower power circuits for our display drivers. We had some very novel design techniques which were done within Hewlett-Packard to give us very low-power LED drivers.



"Drivers for the display are a significant part of the power consumption. We'd like to see an IC vendor come up with some lower power display driver techniques which we could use.

"Or we may have to work on them ourselves. There's a lot of talk about the power consumption of the display itself, but there ought to be more concern about power consumption of the drivers for the display."

Wanted: Low-cost LCD drivers

Next, Dick Bader of Integrated Microsystems, Inc. discussed the problems of electronic watch designs:

"Our company was formed about 2-1/2 years ago and one of the purposes of it was to take a look at what's happening in the packaging of high-technology semiconductor-oriented products—products that have very high semiconductor content. We gravitated toward watches very quickly because they form a particularly unique set of conditions which are very challenging to the semiconductor industry. Among the conditions that are most challenging are size, weight and power dissipation. When we looked at it, we got involved in great depth with a major watch manufacturer, and together over the last year or so we have been coming up with various new designs, some of which are on the market today.

"Our first movement into the area was to use the semiconductor technology that was available at that time, along with present dial displays. We used a synchronized motor and crystal and a very crude CMOS device. Since that time a number of things have developed.

"The watches that are on the market today have some major constraints, and I believe those constraints have to do with size. It all centers around two elements within the watch; that is, the crystal and the battery. Both of these things dictate power dissipation of the watch circuit, and consequently the design. Typically we're talking about batteries that are as high as 0.19 and 0.21 inches. Obviously we've got to get the batteries down in size, or that's a very, very thick wrist watch.

"The other major problem is the crystal. Right now we've standardized it as a result of looking at the speed/power relationship of CMOS on 32 kHz, which has been pointed out in the past. As you increase the frequency, you increase the power (we're working with 11 μA units for batteries). Of course, one of the major constraints is that the battery lasts only for a period of one year. So we find that with our present constraints on CMOS, on batteries and on displays, which are another major problem of high power dissipation, we're talking about liquid crystal displays. There you've got as much as about $5\times10^9\Omega$/centimeter/segment. On the LED displays, even if you multiplex with a 16% duty cycle, you're talking about kinds of power that you just can't stand unless you interrogate.

"Therefore, what we are looking for in the future is lower cost CMOS. To drive liquid crystals for example, we talk about having a dc converter in the watch capable of moving the voltage up to 12V so that we can drive the LCD. We're talking about a very, very large chip with a lot of real estate, low yields and high costs. Our objective is to be able to sell our liquid-crystal watch in the $30 range, which means that we have to build it for about $4 or $5. Today, that is physically impossible. And so, we're looking for some new advances in technology.

"We're looking at SOS to see whether or not that's going to buy us anything in power. We're looking for new advances in batteries. And we're looking for higher packing densities and higher frequencies so that cost and size of the crystal comes down without having to pay a penalty for power.

"I think those are the challenges for the watch industry. And in my estimation, the watch industry is one of the most interesting and fastest growing areas in the new applications for semiconductor devices."

High speed desired over low power

Dick Hall is chief engineer of instruments at Systron Donner. His product areas include frequency counters and digital voltmeters.

Dick discussed his reasons for not using low-power logic: "As an instrument manufacturer, our interest is primarily to use one of the highest technologies for the lowest cost. Cost has been the bind that we find ourselves in with this very tempting carrot called low-power logic.

"Back in the early fifties the instrumentation industry was built on MIL-type vacuum tubes. Along came the transistor, and devices then used were out of the computer industry. The 2N404, a marvelous device, produced a lot of instruments. Then someone produced the integrated circuit, and again the industry was oriented around computer-type devices. Presently we're still oriented around the computer IC's, although a lot of entertainment devices are finding their way into our test instruments.

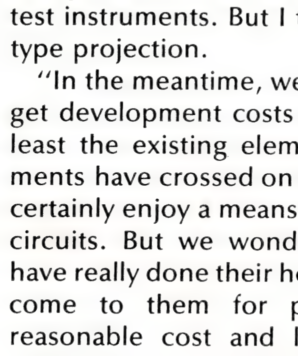
"Low power in general test equipment today is not really a requirement. Our instruments are still bench operated, but field applications are becoming more important to us. But again we are still operating on a 4- to 8-hour battery life.

"The paradox we found ourselves in with MOS devices is that all the advantages of high complexity can be obtained, plus high density and low power. All, however, are overshadowed by something called competition.

"The extremely high cost of developing proprietary chips is limiting us. In the area of test instruments, the number of units sold per year will never approach that of a watch. Therefore, we are a special market. The test instrument market has not yet, I feel, been explored. At present we're very selectively replacing 7400 TTL with equivalent CMOS devices. But, again very selectively, we're beginning to implement MOS-type elements. We're using some Mostek, National and TI devices. Again, though, cost is the objective. Liquid-crystal readouts or something along that line will certainly find their way into test instruments. But I think that's a 5- or 10-year type projection.

"In the meantime, we can wait for IC makers to get development costs down to a level where at least the existing elements and low power elements have crossed on the cost curve. We would certainly enjoy a means of developing proprietary circuits. But we wonder if their manufacturers have really done their homework in allowing us to come to them for proprietary circuits at a reasonable cost and low quantity. They can't really do it our way and we can't afford to do it their way. The question we might ask of IC manufacturers would be how do you propose to serve us if you intend to service the test equipment market? These are not the watches and hand-held calculators; these are the 20- and 30-GHz frequency meters. The need is there; certainly, the desire to use the parts is there, but we're somewhat restricted today.

"In summary then, we at Systron Donner are using low-power devices very selectively and very carefully on a cost-competitive basis."



"Our units do have a need for high-power, high-speed devices, not in the 1 MHz area but in the 10's and 100's of MHz. I don't know whether the "state-of-the-art" will ever achieve that.

Questions and answers

Next came questions from the audience:

Q: "Tom Whitney, you advised that low-power ROM's are now being used in new calculator designs. Please describe this low-power ROM. Who is the supplier? Is it an "in-house" H-P product? What process is employed? What is the ROM size? What power supply voltages are employed and what is maximum power dissipation and maximum access time?"

A: "I'll answer some, then maybe I'll just give you my calculator and you can take it apart.

"The ROM size is 1024 words by 10 bits/word, so it's essentially a 10,000-bit read-only memory. We are presently getting parts from Mostek and American Microsystems. We have a development contract with National Semiconductor, which is not yet completed, but we will soon be receiving prototype parts. The supply voltages are the same as the rest of our calculator which is +6 and −12V. Power consumption of the part is specified to be less than 20 mW and the parts we have seen from the two vendors are between 10 and 20 mW. The HP-45, and the HP-46 calculator, which is desk top version of the 45, now use this part. It will soon be replacing the hybrid circuit which we are now using in the HP-80 calculator.

"In the HP-80 calculator we had to go to seven of the smaller ROM circuits. To do this in the same package size, we had to go to a multi-chip package, and we found that was a relatively expensive solution.

"Access time is not a problem with the kind of architecture that we're using in our calculator, where the basic clock rate is 200 kHz. But we operate on a word-serial basis, and each word has 56 bits in it. We essentially only have to make one access to this ROM per word time. There is a brief discussion of the architecture of the HP-35 calculator in the June, 1972 issue of the H-P Journal, and that's as much as we've said about the architecture and probably as much as we will say for awhile."

Q: "Tom Whitney, why four hours operating time for the H-P calculators? Could you give me some more background and detail and can you give the power consumption in percentages used for logic and displays?"

A: "The selection of four hours was somewhat arbitrary. I guess you have to start somewhere in picking what your design specifications are going to be. Looking at how a typical portable calculator might be used (in the field where the portability and battery operation is important), we felt that four hours of operating time would take care of the person for his full day. He can then come back and, overnight, recharge his batteries and have his calculator available for the following day. It's sort of a complete cycle. As I said, we have had over 1-1/2 years of customer response to integrate and to look at. We receive very few calls or letters regarding a longer operating time.

"The way it turns out, the MOS processor is approximately 25% of the power consumption. The LED display, of course, is a function of how many digits you're lighting up, but let's say on the average it runs about 25% of the power. Drivers for the display represent approximately 25% of the power consumption, the remaining 25% are taken by the clock driver and power supply.

"We have about an 85% efficient power supply, so we lose about 15% of our power trying to get the +6 and −12V off a 3.75V battery supply.

"That's a rough measure of where the power goes."

Q: "Dick Hall, do you feel that the energy crisis will force manufacturers of electronic equipment into considering low-power devices? What if the day comes that you can't stick it into the wall and get everything you need?"

A: "I think before we get to that point we'll be turning our lights off in the building, because the instrument power is a small percentage of the total power within any industry.

"No, I don't think the energy crisis will do it. I think size and performance will be more the push toward getting us to lower power devices because we can get more in the same size box."

Q: "Tom Whitney, when do you expect to see serious competition for your type calculator?"

A: "About a year ago! We've been surprised, very surprised.

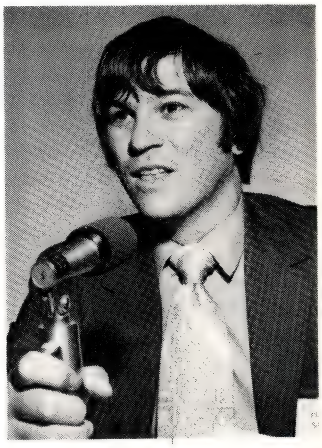
"We thought perhaps we would have about a 9-month competitive advantage in the area of our products. I think some of our competition is finding that it's more difficult to build a scientific calculator than you might imagine.

"It's not the same kind of a product as a 4-function calculator. It's much more complex—you need a different kind of architecture and a different kind of processor. You have much greater difficulty checking out your algorithms. We've been in the scientific calculator business since 1967 and we even found some problems with our algorithms, as you probably know. So there's a different kind of marketing that's required.

"But to answer the question of when do I think—certainly soon. There will be the Rockwell chip. You can go down to Anaheim, buy a scientific calculator chip, put a keyboard and display with it, and you can be in the scientific calculator business. It's going to be more like the 4-function business in the future. I think in the next year we'll be seeing quite a bit more. I think we've shown that there's a bigger market out there than most people imagined."

Q: "Dick Bader, you mentioned that some of the CMOS watch circuits that you first used were "crude." I was wondering if you could elaborate on that?"

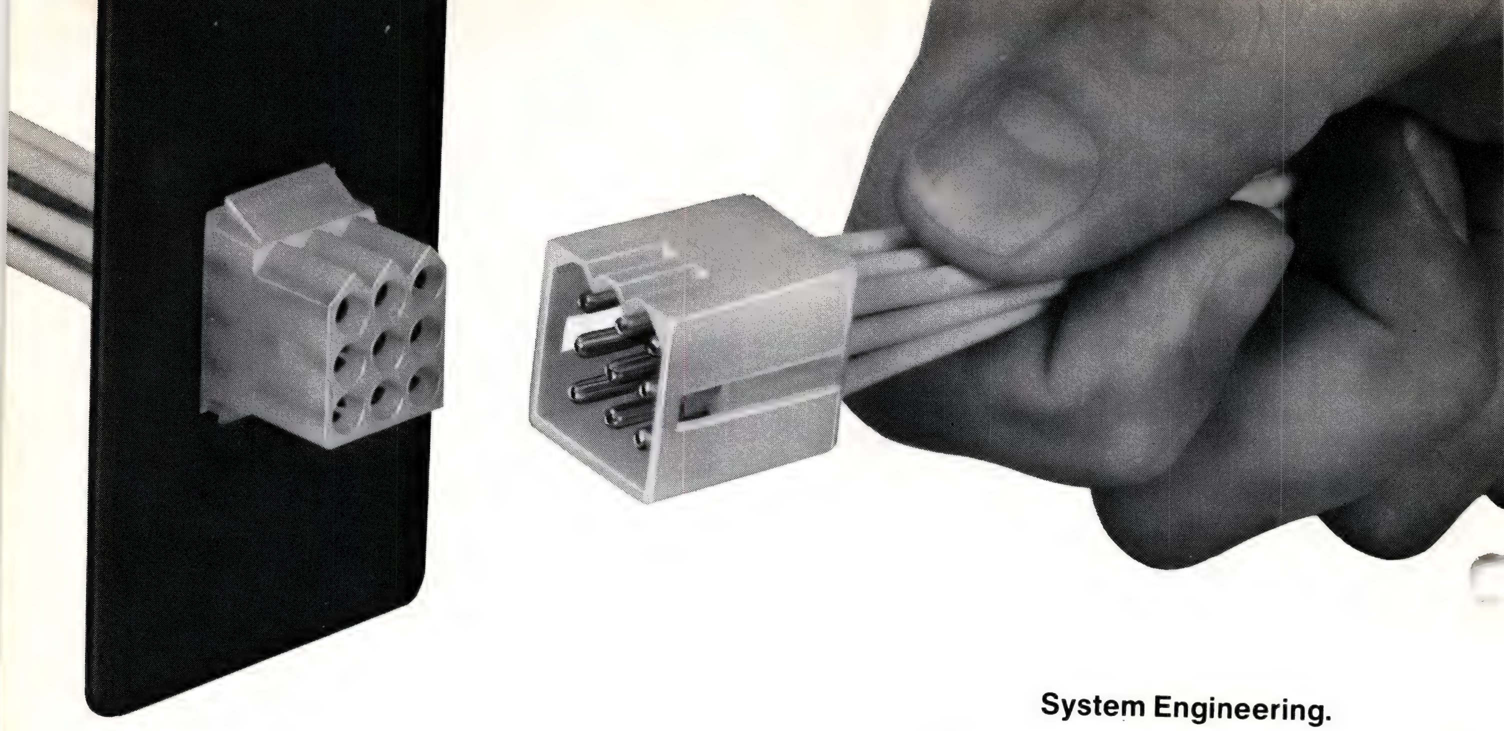
A: "Crude in the sense that the amount of function that was in the CMOS circuit in the early days was relatively small compared to the cost of that circuit. The modern circuits we've been using are custom developed, and on those circuits the chips are very much larger. Costs are higher and you get things like the oscillator amplifier on the chip now. And you get most of the decoding for your readouts on the chip itself. You find that the only thing left that you've got to put on the outside is the dc/dc converter, the capacitors and the crystal, so it's getting much better. But the cost isn't.



"Cost is the key thing. There are two areas where we need help: First, packing density should be increased; and, second, the cost is still too high."

Q: "Dick Bader, what must the circuit and display cost be in the '74-'76 period to meet your $30 objective?"

A: "That really narrows down to what the cost of the chip needs to be. I think the mark-up in the consumer area is unreal compared with what we're used to in the OEM business. This is just a guess, but I think that in order to sell the watch for $30, the cost to produce the entire watch has to to be $5 to $8. If it's anything higher than that, then I don't think you can achieve the $30 retail price." □



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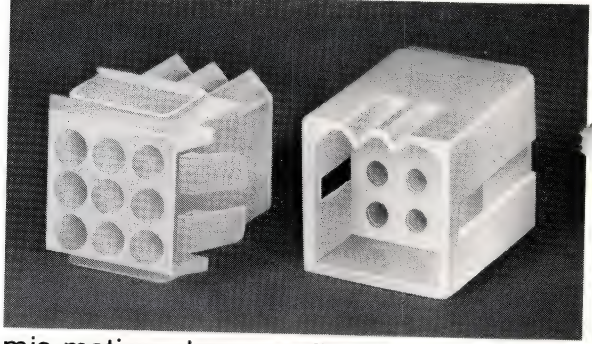

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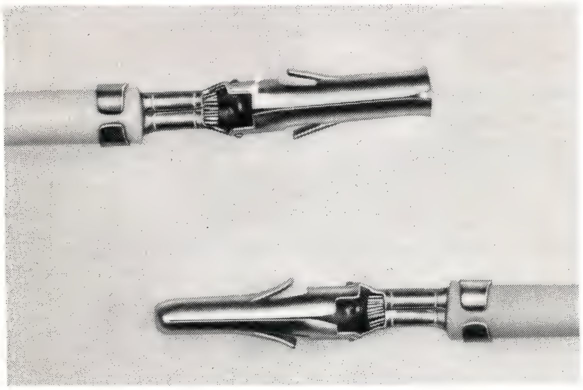

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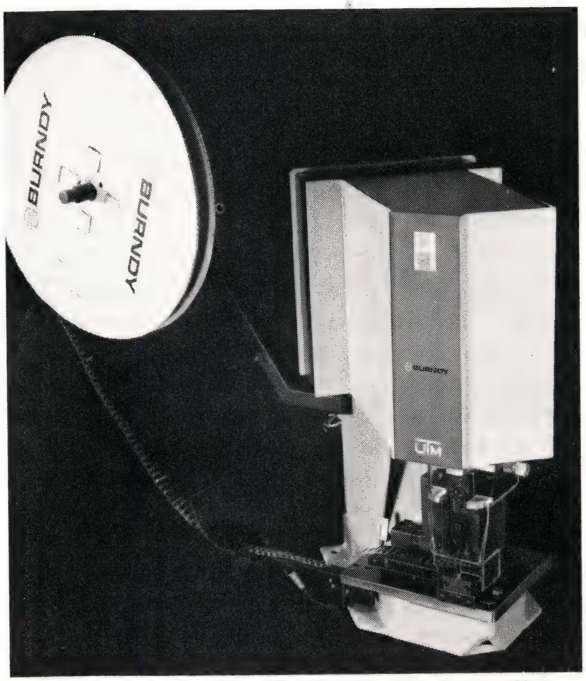

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EDN DESIGN AWARDS

Comparator is part of its own measuring system

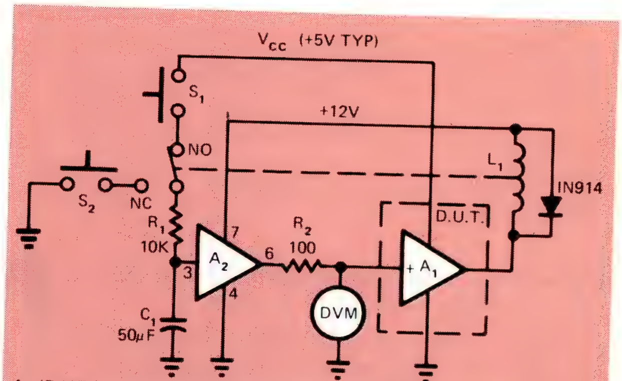
E. S. Papanicolaou,
National Semiconductor, Santa Clara, CA

One common method of measuring comparator thresholds is to use a programmable power supply as the voltage source. But the difficulty with this procedure is that noise spikes in the supply switches may trip the comparator prematurely. The system presented here is a simpler, more convenient way of measuring the upper and lower thresholds of a comparator with 10% hysteresis. It is particularly interesting because the comparator itself becomes part of the measuring system.

The circuit shown is for a noninverting comparator. Switches S_1 and S_2 are momentary types that do not close simultaneously. With capacitor C_1 discharged, relay L_1 is energized. Closing S_1 allows C_1 to charge towards V_{CC}. When the comparator upper threshold is reached, the relay drops out, interrupting the "capacitor charge" cycle. Similarly, closure of S_2 starts a "capacitor discharge" cycle which stops when the lower threshold is reached.

At the end of both cycles, upper and lower thresholds can be read with the DVM. Voltage follower A_2 buffers the capacitor voltage. If the comparator is an inverting type, the relay contact connections should be interchanged.

Best system accuracy is achieved with long R_1C_1 time constants (≈400 msec) and short relay operate times (≈300 μsec). □



A_1 (D.U.T.): NON–INVERTING COMPARATOR WITH
10% HYSTERESIS UNDER TEST
A_2: VOLTAGE FOLLOWER, LM310
L_1: RELAY, COUCH 2X10B460A

Upper and lower thresholds are read on the DVM at the end of capacitor charge and discharge cycles initiated by switches S_1 and S_2. Circuit shown is for a noninverting comparator; reverse the relay connections if an inverting type is tested.

**To Vote For This Circuit
Circle 150**

Variable-frequency oscillator features low distortion

Richard Gunderson
ADC Telecommunications, Minneapolis, MN

A relatively low-cost means of implementing a variable-frequency sine wave oscillator is to use an Intersil 8038. There is an inherent problem with this device, however. It is difficult to maintain low distortion while adjusting a single biasing resistor for any given frequency within a relatively wide frequency range. The solution is to use a fixed biasing network and to adjust the frequency with a circuit simulating a variable capacitor.

Op amps A_2, A_3 and A_4 and their related components form the capacitor simulator. Adjusting potentiometer R_3 varies the equivalent capacitor value from approximately 500 pF to 0.01 μF, a variation of 20:1. For the component values shown, the output frequency range is 175 to 3500 Hz. This range can be extended by adjusting the value of R_6 and R_5, based on the expression:

$$C_{eq} = \frac{C_1(R_3 + R_6)}{R_5}$$

To achieve minimum distortion, R_{SEL} is chosen for 50% duty cycle at A_1, pin 9. R_1 and R_2 are adjusted for minimum distortion, due to the

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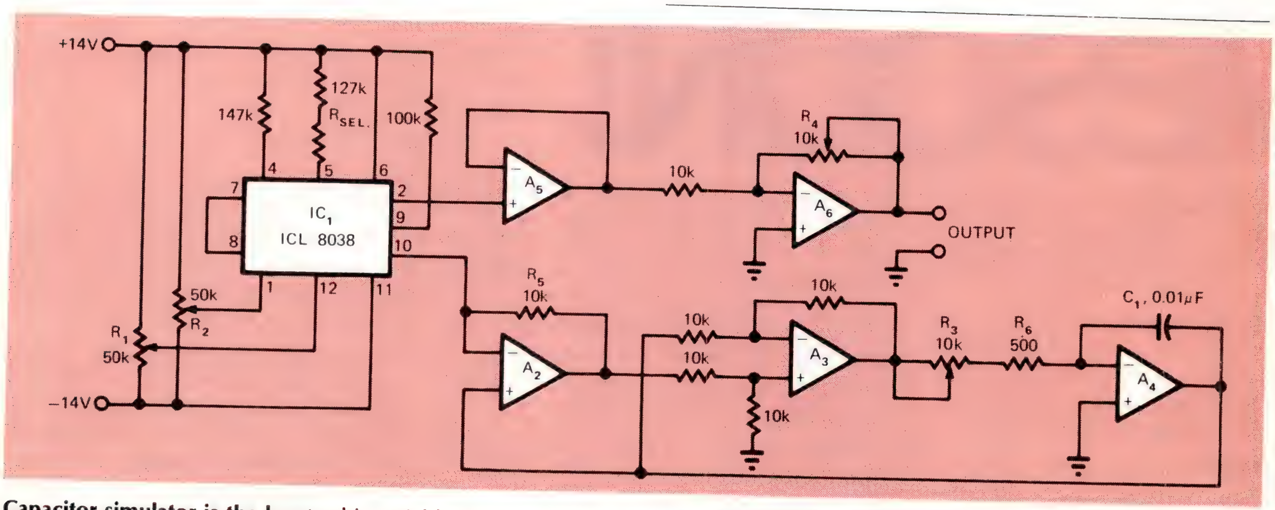
triangle-to-sine-wave converter in A_1. Net distortion for this overall circuit is on the order of 1% or less over the entire frequency range.

Buffer amplifier A_5 provides a high load impedance to IC_1 and a low source impedance to the variable gain stage, A_6. The output circuit can be modified to a single-amplifier variable-gain stage if the input impedance of this network does not load down the output of IC_1.

Cost of this circuit depends on the user's requirements and the quality of the components required to meet those requirements. The circuit operates quite well with any 741-type operational amplifier. □

To Vote For This Circuit
Circle 151



Capacitor simulator is the key to this variable-frequency oscillator. For component values shown, frequency varies from 175 to 3500 Hz. Distortion over this range is less than 1%.

Temperature measurement method requires no reference

Jim Simmons and **Donn Soderquist,**
Precision Monolithics, Santa Clara, CA

Matched transistor pairs have predictable relationships that make precision temperature measurements possible. For example, the expression for the difference in the base emitter voltages for an ideal pair is:

$$\Delta V_{BE} = \frac{KT}{q} \log_e \frac{I_{C1}}{I_{C2}}$$

Note that if the ratio of collector currents I_{C1} and I_{C2} is constant, ΔV_{BE} is proportional to absolute temperature alone.

This concept was applied to satisfy a requirement for a temperature measurement system accurate from −55 to +125°C. Other goals included ease of calibration, long-term stability, standard resistor values, small size, and the ability to locate the sensor up to 100 feet from the remainder of the circuit. **Fig. 1** is the block diagram; **Fig. 2**, the complete schematic.

Since system accuracy is directly related to the degree of matching of the sensing pair, Q_1 was selected with a typical offset voltage TC of 0.15 µV/°C. Similarly, the two most important current-source transistor matching characteristics required are h_{FE} and long-term offset voltage stability, assuming that this portion of the circuit is not subject to wide temperature variations. Therefore Q_2 was selected for its combination of 0.2 µV/month drift and 1% (typ.) h_{FE} match.

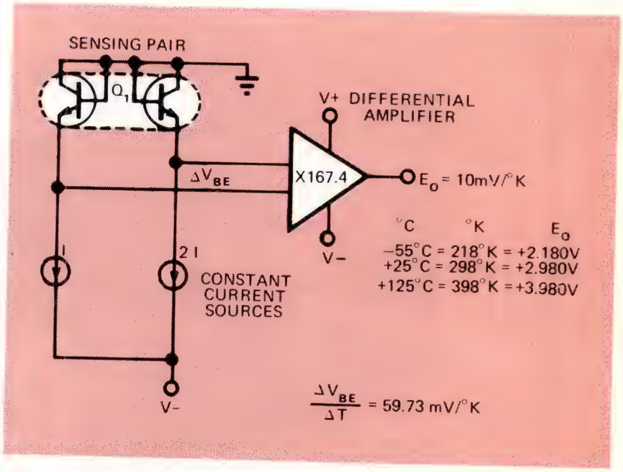
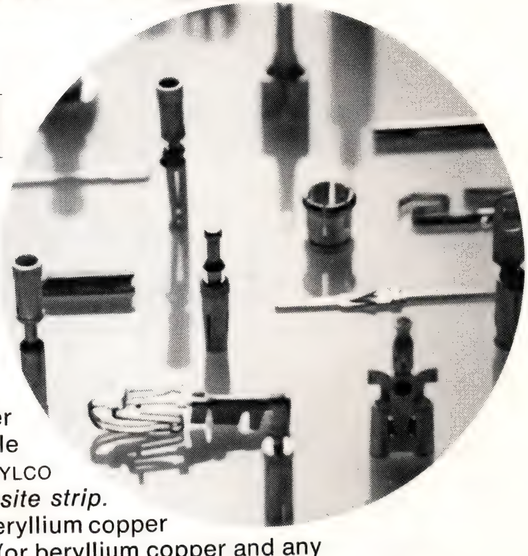


Fig. 1—ΔV_{BE} is proportional to absolute temperature alone if the ratio of the collector currents of the matched pair is constant.

The cost of upgrading product quality with Beryllium Copper connectors can be surprisingly low. KBI can show you how.



The consumer has joined forces with industry to insist on higher levels of product performance. One solution is to upgrade connector reliability with BERYLCO® beryllium copper.
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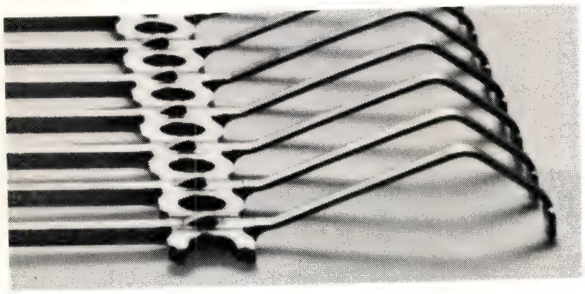
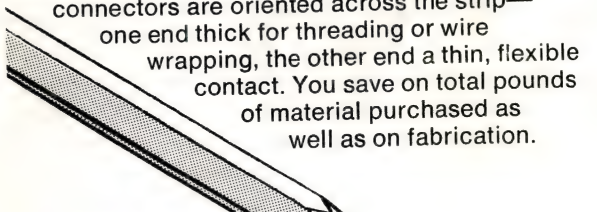


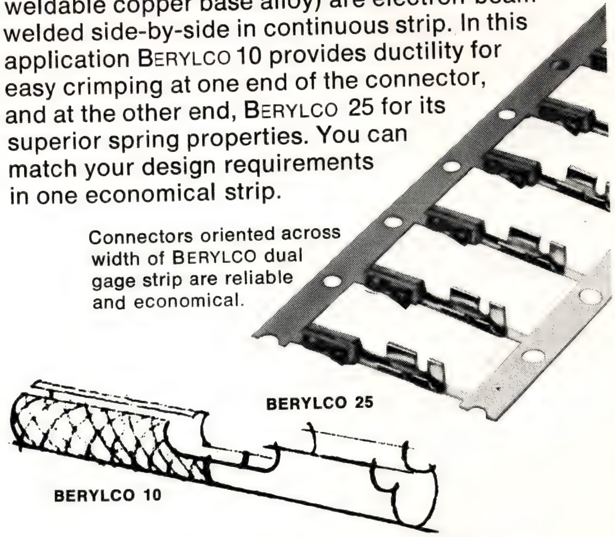
The key to low cost use of BERYLCO beryllium copper is to redesign to take advantage of its unique properties and the special forms available from KBI. Wider, more economical widths permit orienting connectors across the strip. And usually you can use thinner sections of beryllium copper than other materials such as phos bronze. Further savings arise from the special forms of BERYLCO beryllium copper available to you.

Here the designer used BERYLCO *dual gage strip.* Continuously milled to a dual thickness, connectors are oriented across the strip—one end thick for threading or wire wrapping, the other end a thin, flexible contact. You save on total pounds of material purchased as well as on fabrication.



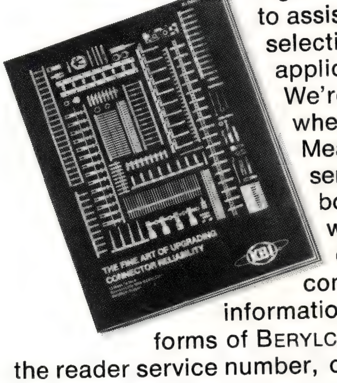
Two tips for designing with dual gage strip: avoid high stresses at the point where thickness changes; and form the part with the milled surface in compression.

Another example is BERYLCO *composite strip.* Two beryllium copper alloys (or beryllium copper and any weldable copper base alloy) are electron-beam welded side-by-side in continuous strip. In this application BERYLCO 10 provides ductility for easy crimping at one end of the connector, and at the other end, BERYLCO 25 for its superior spring properties. You can match your design requirements in one economical strip.



Connectors oriented across width of BERYLCO dual gage strip are reliable and economical.

Although the heat-affected zone is usually less than .050 inch wide, permitting sharp bends anywhere in the strip, the best designs avoid high stress in the weld area. KBI provides a complete engineering advisory staff to assist you in materials selection and special application problems. We're ready to help when you need us. Meanwhile, why not send for this new booklet? It's packed with connector design ideas, comparative data and information about the many forms of BERYLCO alloys. Just circle the reader service number, or contact us directly.



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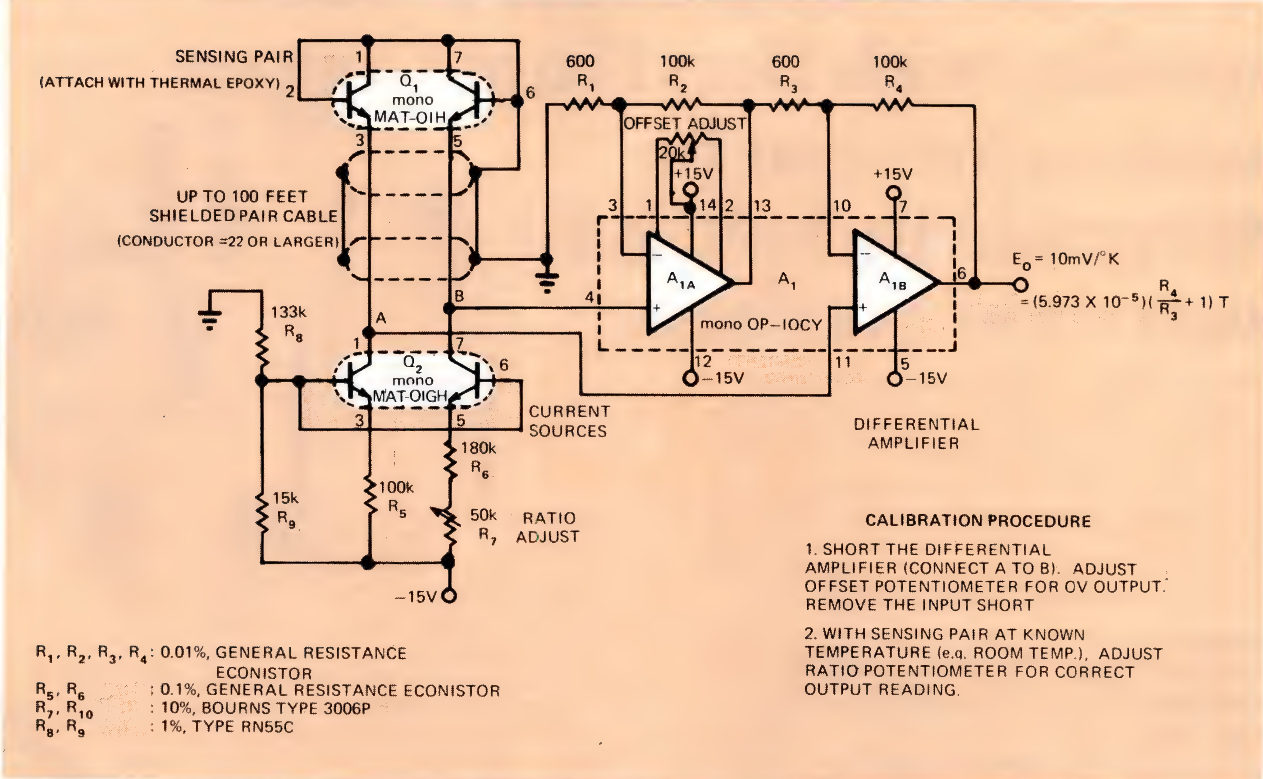
Circle No. 41



$$= (5.973 \times 10^{-5})\left(\frac{R_4}{R_3} + 1\right) T$$

R_1, R_2, R_3, R_4 : 0.01%, GENERAL RESISTANCE ECONISTOR
R_5, R_6 : 0.1%, GENERAL RESISTANCE ECONISTOR
R_7, R_{10} : 10%, BOURNS TYPE 3006P
R_8, R_9 : 1%, TYPE RN55C

CALIBRATION PROCEDURE

1. SHORT THE DIFFERENTIAL AMPLIFIER (CONNECT A TO B). ADJUST OFFSET POTENTIOMETER FOR 0V OUTPUT. REMOVE THE INPUT SHORT
2. WITH SENSING PAIR AT KNOWN TEMPERATURE (e.g. ROOM TEMP.), ADJUST RATIO POTENTIOMETER FOR CORRECT OUTPUT READING.

Fig. 2—Accuracy is ±1°K over−55 to+125°C, yet parts cost is less than $35. Other circuit features include easy calibration at room temperature, standard resistor values, small size and excellent long-term stability.

When the differential amplifier is considered, important parameters are common mode rejection (CMR) and the difference between the input offset voltages of the two op amps. CMR is most critical at low temperatures. At −55°C, ΔV_{BE} is only 13 mV, yet the common mode voltage is 696 mV. (Keep in mind that this is a best case and disregards any extraneous cable pickup.) Obviously, the requirement for high CMR is very real. However, because the dual op amp specified has a 117 dB CMR match, no special op amp selection is required and the ability to reject common mode inputs becomes primarily a function of resistor ratio matching.

Resistor selections can be avoided by using readily available 0.01% tolerance precision resistors, resulting in a worst-case ratio match of 0.04%. This ratio match, in combination with the dual op amp's performance, results in greater than 100 dB common mode rejection at the amplifier's input.

Long-term stability of the resistors must approach the initial ratio match, or degradation of common mode rejection can occur over time. The resistors chosen are specified at ±50 ppm/3 years and ±5 ppm/°C, thereby assuring stability versus time and temperature.

Calibration is an easy 2-step procedure (**Fig. 2**), and can be accomplished at room temperature. Once calibrated, this circuit, with components as specified, is capable of ±1°K accuracy over the full military temperature range. Yet total parts count, based on 100-pc prices, is less than $35.

Optimum accuracy is obtained with the differential amplifier and constant-current sources in a controlled environment remote from the sensing pair. Accuracy is maintained over long periods of time due to the stable components specified. ☐

To Vote For This Circuit
Circle 152

Variable voltage power supply uses minimum components

Lewis Drake,
Industrial Nucleonics Corp., Columbus, OH

The power supply circuit (**Figs. 1** and **2**) is continuously adjustable from approximately zero to 20V (the minimum output voltage is a function

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Circle No. 42

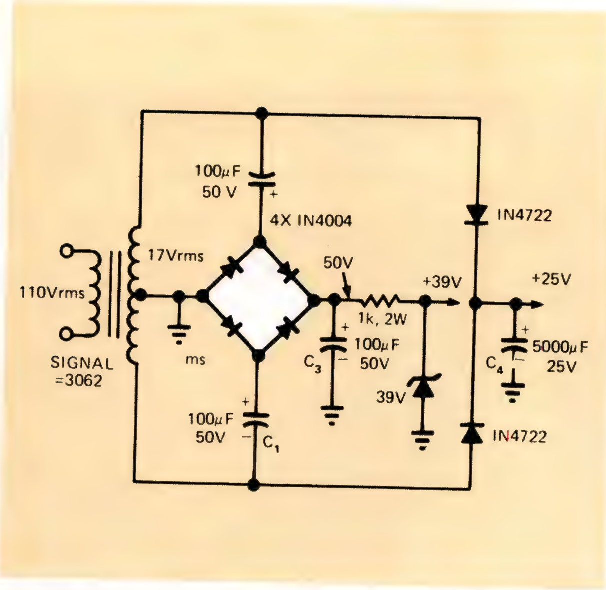

Fig. 1—Full-wave voltage doubler of a novel design provides the +39V required by the 723 regulator.

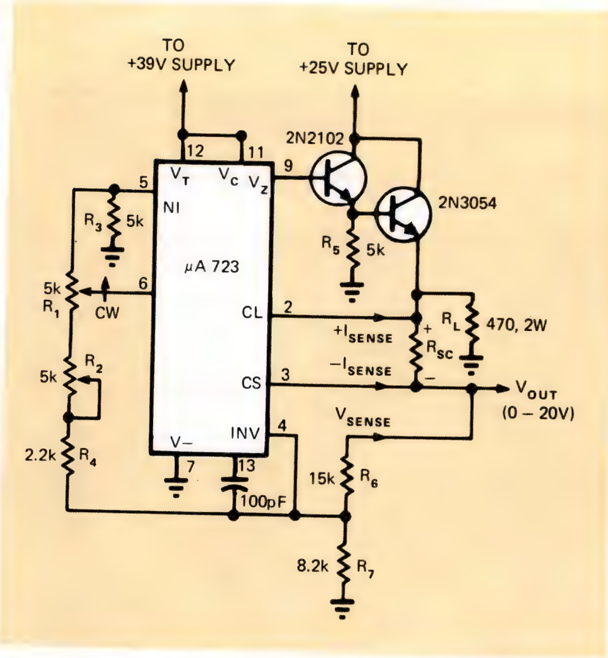

Fig. 2—Bridge circuit formed by R_1, R_3, R_2 and R_4 prevents saturation of the input stage of the 723. R_{SC} determines the short circuit current; R_1, the output voltage.

of the leakage current in the final pass transistor). A current limit feature (standard in the 723 IC) is included. Current limiting resistor R_{SC} in **Fig. 2** is chosen such that:

$$R_{SC} = 0.65/I_{SC}$$

where I_{SC} is the short circuit current desired.

The raw dc supply shown in **Fig. 1** provides two different outputs. This is done in order to limit power dissipation in the pass transistors at low output voltages and large load currents because a voltage at least 10V above the output is required on pins 11 and 12 for proper operation of the 723.

C_4, the 5000 µF capacitor, was selected to provide a 3V ripple at 2A load current. For other values of load currents and output voltages, C_4 can be calculated by assuming a constant discharge current equal to the maximum load current. A novel full-wave voltage doubler formed by the diode bridge and capacitors C_1, C_2 and C_3 supplies the 39V required by the 723.

In **Fig. 2**, the bridge circuit formed by R_1 and R_3 in one leg, and R_2 and R_4 in the other, allows the potential on pins 5 and 6 to be maintained above 3.5V as R_1 is changed. This prevents saturation of the input stage of the 723. R_2 is adjusted for minimum output voltage when R_1 is in the counter-clockwise position. This balances the bridge when $V_{OUT}=0$. The output voltage will then be proportional to the position of R_1. □

To Vote For This Circuit
Circle 153

Readers have voted:

Bascom Dillon and **Roger Dimmick** winners of the January 5, 1974 U.S. Savings Bond Award. Their winning circuit is "Sample-and-hold circuit features good accuracy." Mr. Dillon and Mr. Dimmick are with the IBM Corp., Boca Raton, FL.

Larry Gene Smeins winner of the February 20, 1974 U.S. Savings Bond Award. His winning circuit is "S"-shaped sawtooth oscillator." Mr. Smeins is with Ball Research Corporation, Boulder, CO.

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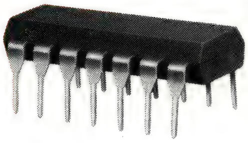
741's.



If there ever was a linear IC destined to become the biggest volume commodity item since the 741, it's Raytheon Semiconductor's 4136 Quad Op Amp.

The 4136 is the only quad op amp that's electrically equivalent to four 741's. The only one that requires no design changes. And it's even better than the 741. Lower input noise, better input offset voltage matching, wider input common mode voltage range, greater gain, higher slew rate, and wider bandwidth.

The 4136 costs 40% less than four 741's. And that's just the beginning. Packaged in a standard commercial or military 14-pin DIP, it requires only one mechanical assembly step. So naturally it takes up less board space. Testing is simpler too. And inventory is less of a problem. This all adds up to greater cost savings.

There's more to the big 4136 design-in number story. Get all the facts on quads.

Raytheon Semiconductor
350 Ellis Street
Mountain View, California 94042

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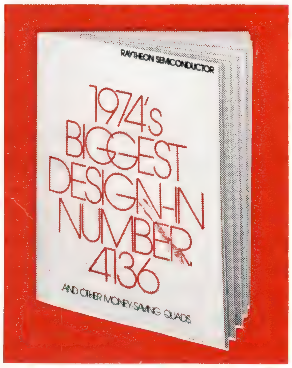

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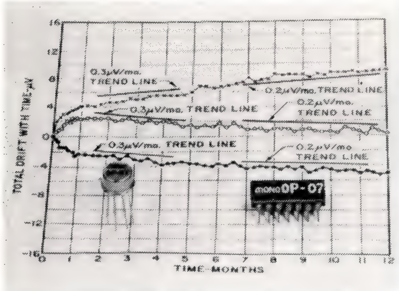


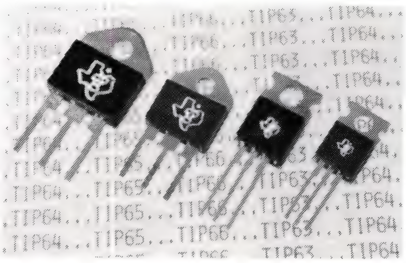
LOW-COST, LOW-DRIFT OP AMP CHALLENGES CHOPPERS. Mono OP-07 features typ. input offset voltage of 10 μV, 0.2 μV/°C drift (−55 to +125°C), and 0.2 μV/mo. stability. No large external compensating or holding capacitors, resistors or potentiometers are required. Other key specs include ±14V CMV range, 126 dB CMRR, 2 nA I_B and 0.6 μV p-p max. noise. Prices (100) range from $9.95 for the 125 μV (max E_{os}) version to $60 for the 25 μV unit. Precision Monolithics Inc., 1500 Space Park Dr., Santa Clara, CA 95050. Phone(408)246-9225. **239**

ECL COUNTERS OPERATE ABOVE 100 MHz. The 10136 is a 16-state synchronous counter; the 10137, a 10-state unit. Both have 4 operating modes—count up, count down, preset and stop—controlled by 2 function-select inputs. Other features include a carry-in and carry-out and 4 data inputs. Manufactured in ceramic DIL packages, the 10136 and 10137 each sell for $13.55 (100). Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **240**

INTERFACE IC'S ARE USEFUL FOR BUS-ORIENTED DATA SYSTEMS. There are 9 new TTL devices in the series, including 2 transceivers (8T34 and 8T38), a receiver (8T37), 2 high-speed inverters (8T93 and 8T94) and 4 fast buffers and inverters with tri-state outputs (8T95-8T98). Prices range from $1.43 to $2.04 (100). Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. Phone (408)739-7700. **INQUIRE DIRECT.**

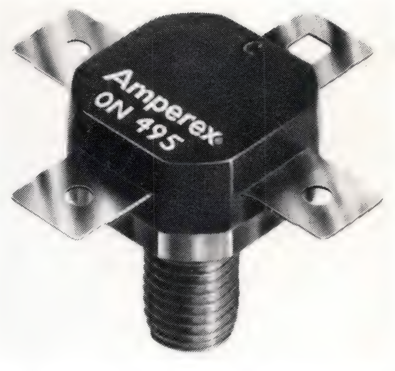
QUAD CURRENT-MODE BUS DRIVERS OPERATE IN 4 NSEC. Inputs of the 10192 are compatible with all other devices in the ECL 10,000 series. Outputs are 16 mA open-collector, switched current sources. Complementary outputs can be switched to one of 3 logic states, providing a "party line" capability in differential as well as single-ended modes. Open-collector outputs can accept voltages ranging from +5.5 to −1.6V. The 16-pin DIL ceramic 10192 is $6.27 (100). Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **INQUIRE DIRECT.**

MOS FIFO MEMORY STORES UP TO 40 WORDS IN 9-BIT FORMAT. In this first-in, first-out memory (Model 3351), data entered at the inputs automatically propagates toward the output terminals with no clocking required. The device operates at data rates up to 1.5 MHz, has independent asynchronous inputs and outputs and is fully TTL compatible. It also can be easily expanded in width or length to accommodate other data formats. Available in a 28-pin DIL package, the 3351 is priced at $15.60 (100). Fairchild Semiconductor, 464 Ellis St., Mt. View, CA 94042. Phone(415)962-3816. **241**



FOUR SILICON NPN POWER TRANSISTORS OFFERED IN 2 SERIES. The TIP63 and TIP64 Series are high-voltage medium-power transistors featuring V_{CEO} breakdown voltages to 350V. Continuous dissipation at 25°C case temperature is 20W. The TIP65 and TIP66 Series are TV horizontal deflection transistors featuring 1200 and 1400V collector-emitter ratings, 1.5A collector currents and fast switching. Prices are 55¢, 59¢, $1.33 and $1.53, respectively (100). Texas Instruments Inc., Box 5012, M/S 308, Dallas, TX 75222. Phone (214)238-3741. **242**

VHF-UHF TUNING DIODES FEATURE LOW LEAKAGE. SQ5461A-76A tuning diodes are identical to their counterpart JEDEC IN5461A-76A series except for the 4 nA reverse current ratings at 30V. Otherwise, both series cover a 6.8 to 100 pF range of capacitance values in 16 types. Corresponding Q values for these glass DO-7 packaged devices range from 600 to 250 at 4V bias and 50 MHz. Price is $6 (100). MSI Electronics Inc., 34-32 57th St., Woodside, NY 11377. Phone (212)672-6500. **243**



POWER TRANSISTOR DELIVERS 100W AT 130-175 MHZ. Type ON495 has a power gain of 6.4 dB and collector efficiency of 82% at 175 MHz. Designed for both mobile and base-station applications, it delivers 100W of C.W. power with a collector voltage of 28V. The jumbo stud package allows the ON495 to withstand wide temperature variations and mismatch conditions. Price is $45.10 (500-1k). Amperex Electronic Corp., 230 Duffy Ave., Hicksville, NY 11802. Phone(516)931-6200. **244**

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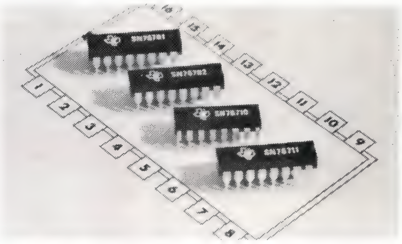

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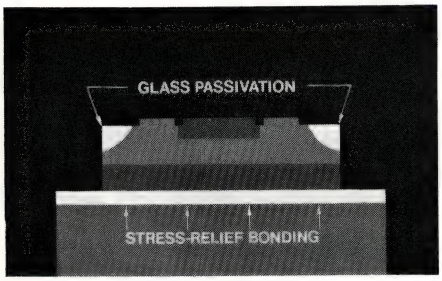

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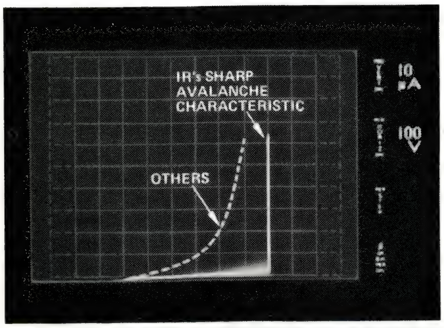

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IR424	DTS 424		MJ424
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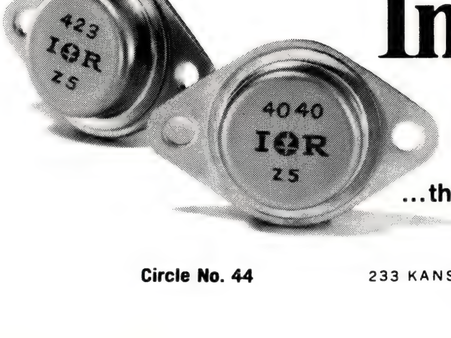

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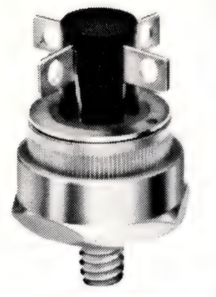

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Circle No. 46

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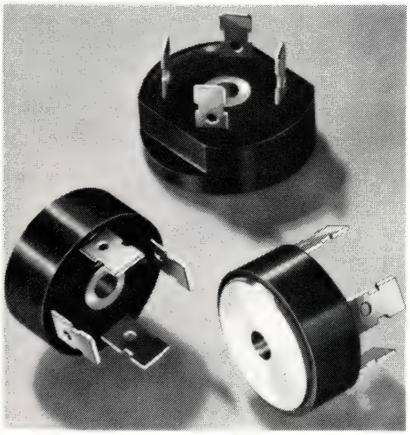
4-LAYER THYRISTORS TURN OFF IN 20 nSEC AT 100 mA. This makes them the fastest thyristor diodes on the market today. Switching voltages are available from 20 to 100V with tolerances from ±4 to ±10V. Most device types have guaranteed switching voltages from −60 to +125°C. Double-plug construction is also featured. Prices start at $2 for 20V types (4E20-8) in 1000's. DO-35 and DO-7 packages are offered. American Power Devices, Inc., 7 Andover St., Andover, MA 01810. Phone(617)475-4074. **247**

TRANSISTORS HANDLE MEDIUM-POWER APPLICATIONS. The 2N5490 through 2N5497 npn plastic power transistors are designed for switching and amplifier circuits. Two other types, 2N6098 and 2N6099 (P_T = 75W @T_C = 25°C) are also available. All replace the TIP29 and TIP31 devices. Specifications of the 2N5490 series include V_{CEO}'s to 70V, I_C = 7A, H_{fe} up to 3A with gains to 100, and P_T = 50W at T_C = 25°C. These TO-220 units are 70¢ (100). Power Physics Corp., Industrial Way W., Eatontown, NJ 07724. Phone(201)542-1393. **248**

IC GENERATES HIGH-QUALITY WAVEFORMS. The XR-2206 generates sine, square, triangle ramp and pulse waveforms with the aid of a simple passive network. The output can be amplitude and frequency modulated as well as frequency-shift keyed. Oscillator range is 0.01 Hz to >1 MHz and frequencies can be swept linearly through 3,000:1 range, typ. Amplitude modulation capability is 100% and duty cycle is adjustable from 0.1 to 99.9%. XR-2206 prices (100) start at $4. R-OHM Corp., EXAR Integrated Systems, 16931 Milliken Ave., Irvine, CA 92705. Phone(714)546-8780. **249**

QUAD OP-AMPS OPERATE FROM SINGLE OR DUAL SUPPLIES. When operated from single (3-30V) supplies, the input common-mode voltage range of the SG124 series includes ground, and the output voltage can also swing to ground. This permits sensing signals at, or very near, ground. Dual supplies (±1.5 to ±15V) can also be used. Current drain is 0.8 mA/pkg; E_{OS}, 2 mV; I_B, 45 nA; and gain, 100 dB. Both plastic and ceramic DIL packages are offered in 3 temperature grades. Prices (100 pcs) range from $2.50 to $10. Silicon General, Inc., 2712 McGaw Ave., Irvine, CA 92705. Phone(714)556-1600. **250**



HEAT DISSIPATES RAPIDLY IN BRIDGE ASSEMBLY SERIES. This is assured by a positive pressure system between the diodes and the thin aluminum base. Four series, 2 rated at 30A, and 2 at 25A, (at 60° C case temperature) are available with either a center thru-hole or a mounting stud. All have a 400A surge rating and are available in ratings from 50 to 1000V. Cost ranges from $3.42 to $5.33 (25-99 quantity). Sarkes Tarzian, Inc., Semiconductor Div., 415 N. College Ave., Bloomington, IN 47401. Phone(812)332-1435. **251**

SCR-CONTROLLED BRIDGE SERIES INCLUDES EXPLOSION-PROOF packages. The series is rated at 25 and 50A dc output with 200, 400, and 600V dc blocking voltages. Four 25A circuits are offered in a 3/4-in. press-package (with 3 mounting options): a power switch; half-wave power switch; center-tapped controlled bridge and common-cathode controlled bridge. Also included are explosion-proof, electrically-isolated epoxy barrier packages with integral mounting pads for low thermal resistance. Varo Semiconductor Inc., Box 676, 1000 N. Shiloh, Garland, TX 75040. Phone(214)272-4551. **252**

MOS/LSI FIRM OFFERS TO SELL TECHNOLOGY. The product in this case is technology in MOS/LSI wafer processing. Offered are p-channel (SATO/PLANOX), silicon gate p-channel, CMOS (metal gate), 3-phase polysilicon charge-coupled devices (CCD) and refractory metal (tungsten) MOS processes. All have been proved-in and tested by independent electronics manufacturers. The basic wafer fabrication technology or any of the proved-in processes may be purchased for approximately $300,000 ea. Mosfet Micro Labs, Inc., Penn Center Plaza, Quakertown, PA 18951. Phone(215)536-2104. **253**

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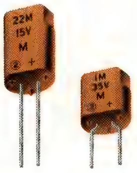

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Economically priced, molded-case Econoline™ capacitors. Standard lead spacing, 0.100″, 0.200″, and 0.250″. Tough, flame-retardant, crack resistant case has flatted section and polarity indicator for easy-to-read marking and error-free insertion. Fixed external dimensions allow increased productivity during assembly of PC boards. Designed for severe vibration and shock environment, where lead support alone is not adequate. Operating temperature range, −55 C to +85 C. Capacitance values from 0.1 to 100μF. Voltage range, 4 to 50 VDC. For complete data, write for Engineering Bulletin 3546.

Call your nearest Sprague district office or sales representative, or write for the bulletins mentioned above to Sprague Electric Company, 491 Marshall Street, North Adams, Mass. 01247.

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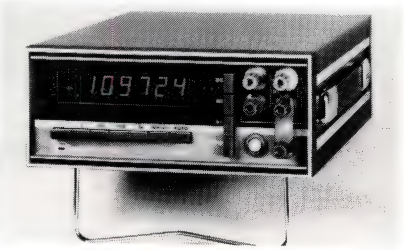
SWEEP/FUNCTION GEN COVERS 2 Hz-200 kHz, SWEEPS 1000:1. The low-cost Model 95 produces sine, square, triangle and swept waveforms as well as fixed-amplitude pulses. Frequency coverage is in 3 ranges, with a linear/logarithmic frequency control. There are slow (25 sec), medium (250 msec) and fast (2.5 msec) sweep rates. High- and low-level sine outputs, both with amplitude control, are provided. A VCF input permits controlling frequency from an external source. Powering from a 9V transistor battery eliminates line-hum problems. $149.50. Exact Electronics, Box 160, Hillsboro, OR 97123. Phone(503)648-6661. **254**

50 AND 150 MHz COUNTER-TIMERS HAVE BECKMAN DISPLAY. Both Model 6305 (50 MHz) and Model 6315 (150 MHz) have adjustable trigger level and trigger lamps. Time measurements with up to 100 nsec resolution are standard. A precision TCXO provides accuracy and stability. Models 6305 and 6315—$495 and $695, respectively. Berkeley Instruments, Inc., 1701 Reynolds, Santa Ana, CA 92705. Phone(800)854-3253. **255**

TESTER DOES "WORST-CASE" CHECK OR μPROCESSOR CHIPS. The BIG "M" tests the individual instructions on a chip in varying sequences to provide worst-case testing. Present techniques only check the logic of the microprocessor without guaranteeing its function. Intended for probe and receiving inspection use, the BIG "M" is applicable for testing memories or microprocessor chips used in products such as digital watches, seat belts and calculators. $50,000. Delivery is 60 days ARO. Macrodata Co., Inc., 6203 Variel Ave., Woodland Hills, CA 91634. Phone (213)370-8551. **256**

PULSE GENERATOR HAS 85% OF ITS COMPONENTS ON 1 IC CHIP. Model 1101 is battery operated, so can be isolated from ground. The batteries provide 40 hrs. of operating time and are rechargeable in 10 hrs. using a charger (included). Frequency range is 0.1 Hz to 2 MHz, fall time is 10 nsec and rise time is 50 nsec. Pulse width is continuously variable from 0 to 100% of the period. Output voltage is adjustable from 0 to 5V. Trigger inputs and outputs are provided, and the pulse output sinks 50 mA, and sources 5 mA, TTL compatible. $159(1), $139(5 up). Interdesign Inc., 1255 Reamwood Ave., Sunnyvale, CA 94086. Phone(408)734-8666. **257**

CIRCUIT BOARD TEST SYSTEM EMPLOYS COMPUTER CONTROL. The semi-automatic Datatester 4400 was specifically designed for low-volume production as well as for troubleshooting and repair stations. Its processor provides stored program capability that permits the testing of boards, devices and the entire module with the exact patterns and timing necessary to do a function test. IC test modules available adapt 14, 16, 24 and 40-pin IC's for testing with the processor. Base price is $6475. Data Test Corp., 2450 Whitman Rd., Concord, CA 94518. Phone (415)689-3583. **258**



AUTORANGING 5-1/2-DIGIT DMM MEASURES FROM 1 μV AND 1 mΩ. Model 3500 features autoranging from 1 microvolt and 1 milliohm through all ranges, 1/2-in. planar display, improved isolated BCD output and local/remote trigger control operation. With 21 ranges it measures dc V to 1000V, ac V to 700V, resistance to 12 MΩ and ratio from ±0.010000/1 to ±100.000/1. $995. Data Precision Corp., Audubon Rd., Wakefield, MA 01880. Phone(617)246-1600. **259**

BROWNOUT- AND BLACKOUT-PROOF POWER SYSTEM FOR COMPUTERS. The PM 2478 is a lightweight 800W multiple-output supply. It operates normally over an input range of 90 to 130V ac, and with power dropouts up to 20 msec in duration. Under blackout conditions, the device automatically switches to battery operation. Standard outputs are 5V at 100A, −15V at 5A and +15V at 15A. All outputs are individually overload and short-circuit protected. Pioneer Magnetics, 1745 Berkeley St., Santa Monica, CA 90404. Phone(213)829-3305. **260**

ELECTRONIC PRINTING CALCULATOR REPLACES ADDING MACHINE. The 10-column Model BC-1003P has a basic adding-machine keyboard. It offers the added capability of "cross-footing," using total and grand-total keys. Calculator functions are performed on the left-hand side of the machine, thereby separating the "calculator" and "adding machine" sections. An 8-stage buffered keyboard allows rapid acceptance of entries (up to 8 entries ahead of the printing mechanism). Size is 9-13/16W×3-5/8H×12-11/16D; weight is 12 lbs. 2 oz. $299.95. Toshiba America, Inc., 280 Park Ave., New York, NY 10017. **261**

TV CAMERA FOR MICROSCOPE USE NEEDS 500× LESS LIGHT INPUT. Equipped with a silicon intensifier target image converter tube, Model 4300/SIT camera is well suited where bright lighting is neither desirable nor available. It will resolve all 10 shades of gray on the EIA-TV Chart with only 3×10^{-4} fc highlight illumination on the camera tube faceplate. A usable picture can be produced with as little as 4×10^{-4} fc. Automatic controls allow for picture contrast to be maintained over the entire 400:1 working light range. Cohu, Inc., Box 623, San Diego, CA 92112. Phone(714)277-6700. **262**

DIGITAL PHASE-ANGLE METER INCLUDES ANALOG NULLING. This permits pre-setting of any off-set phase angle from −360 to +180° and the adjustment of a device under test for phase-shift accuracy of ±0.1°. Model 305D offers precision measurement of phase angles from 0 to ±180° and 0 to +360°, with 5-digit-plus-sign illuminated readout display, 0.01° resolution and an operating frequency range from 2 Hz to 11 MHz. Price: $3200 to $4000, depending on plug-ins and options chosen. Dranetz Engineering Laboratories, Inc., 2385 S. Clinton Ave., South Plainfield, NJ 07080. Phone(201)755-7080. **263**

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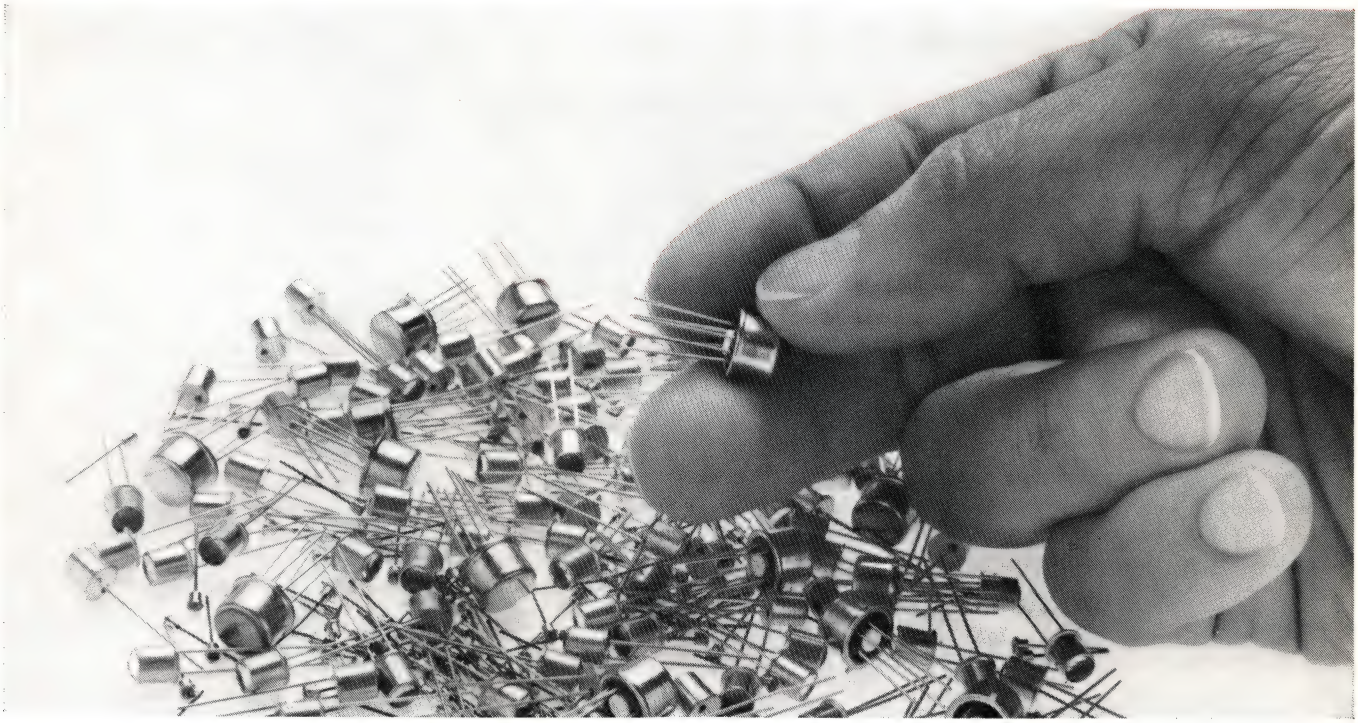

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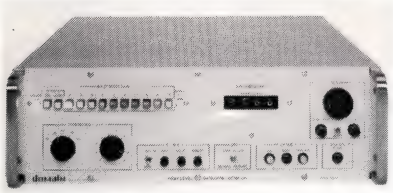
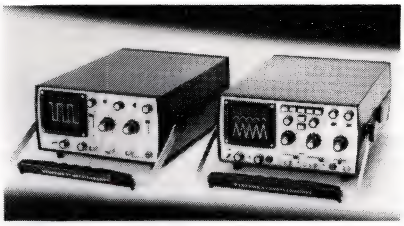


HIGH-LEVEL BASEBAND MONITOR FOR ON-LINE USE. The DS-10 is designed for use in low-density FDM telco offices. It provides an economical means of automatically monitoring high-level signals in VF channels in up to ten 1800 channel basebands inputs. Each input is sequentially scanned from 62 kHz to 8802 kHz in discrete 4-kHz steps, so that each VF channel is automatically monitored and measured. $6000. Delivery 120 days ARO. Domain Systems, Inc., 215M Central Ave., East Farmingdale, NY 11735. Phone(516)293-6504. **264**

LOW-COST DATA LOGGER SAMPLES 1 TO 100 POINTS AT 3/SEC. DATOS 901-P does this with an accuracy of 0.1% and a resolution of 1 part in 2000. Among the standard features are pin-board programming of channel selection, real-time clock and a multirange timer with scan or channel time selection from 0.3 sec to 99 hr. It can be externally expanded to 1000 channels, and all inputs are true floating differential. From $1900. Data Graphics Corp., 8402 Speedway Dr., San Antonio, TX 78230. Phone(512)342-9486. **265**

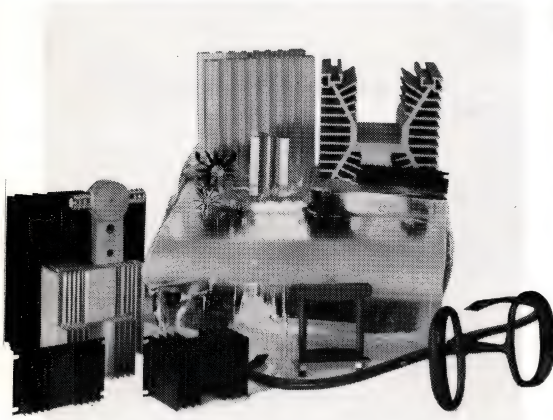


SINGLE OR DUAL-TRACE TRIGGERED SCOPES HAVE DC-15 MHz B.W. Solid-state Models 77 and 87 are priced at $550 and $625. Vertical and horizontal controls are color coded for rapid reading. Both have a flat-face 8×10 div. CRT; full 15 MHz bandwidth and 10 mV sensitivity. Sweep rates are from 0.2 sec/div. to 0.5 μsec/div. in 17 calibrated steps selected in 1-2-5 sequence. Systems Electronics, Inc., 9727 Inglewood Ave., Inglewood, CA 90301. Phone(213)671-8231. **266**

SELF-CONTAINED PYROMETER MAKES 1% MEASUREMENTS. Model 6020's highly-sensitive meter is driven directly from the thermocouple emf. Bi-metallic compensation corrects for changes in ambient temperature. The 6020 is available in ranges from −200 to 2500°F in J, K, R, S and T calibrations. Several companion probes are available, including roller-surface probes, general-purpose probes, needle probes, flat-surface probes and beaded-type wire probes. Omega Engineering, Inc., Box 4047, Stamford, CT 06907. Phone(203)359-1660. **267**

SC MATERIAL TYPING AND RESISTIVITY MEASURING SYSTEM enables all such needs to be served with a single, low-cost instrument. Model 530 works easily with bulk wafers, ingots or epitaxial silicon layers, measuring resistivity and identifying material type on materials with resistivities from 10^{-3} Ω-cm to 10^{4} Ω-cm. Basically, the system combines and interfaces a constant-current source and a digital voltmeter. $1495 exclusive of probe and sample staging. Delivery is 90 days ARO. Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139. Phone (216)248-0400. **268**

DROP-RESISTANT HAND-SIZE VOM DOUBLES AS PROBE. The ruggedized Model 310-Type 3 features a virtually indestructible thermoplastic case and an easy-access battery and fuse compartment. Also, it can be converted into a common probe by simply unscrewing the tip from the black lead and placing it into a special jack on top of the tester. The new tester is a high-torque bar-ring instrument with spring-back jewel meter movement that provides 20,000 Ω/V dc and 5000 Ω/V ac sensitivity, has 18 ranges, and is self-shielded. $48. Triplett Corp., Bluffton, OH 45817. Phone(419)358-5015. **269**



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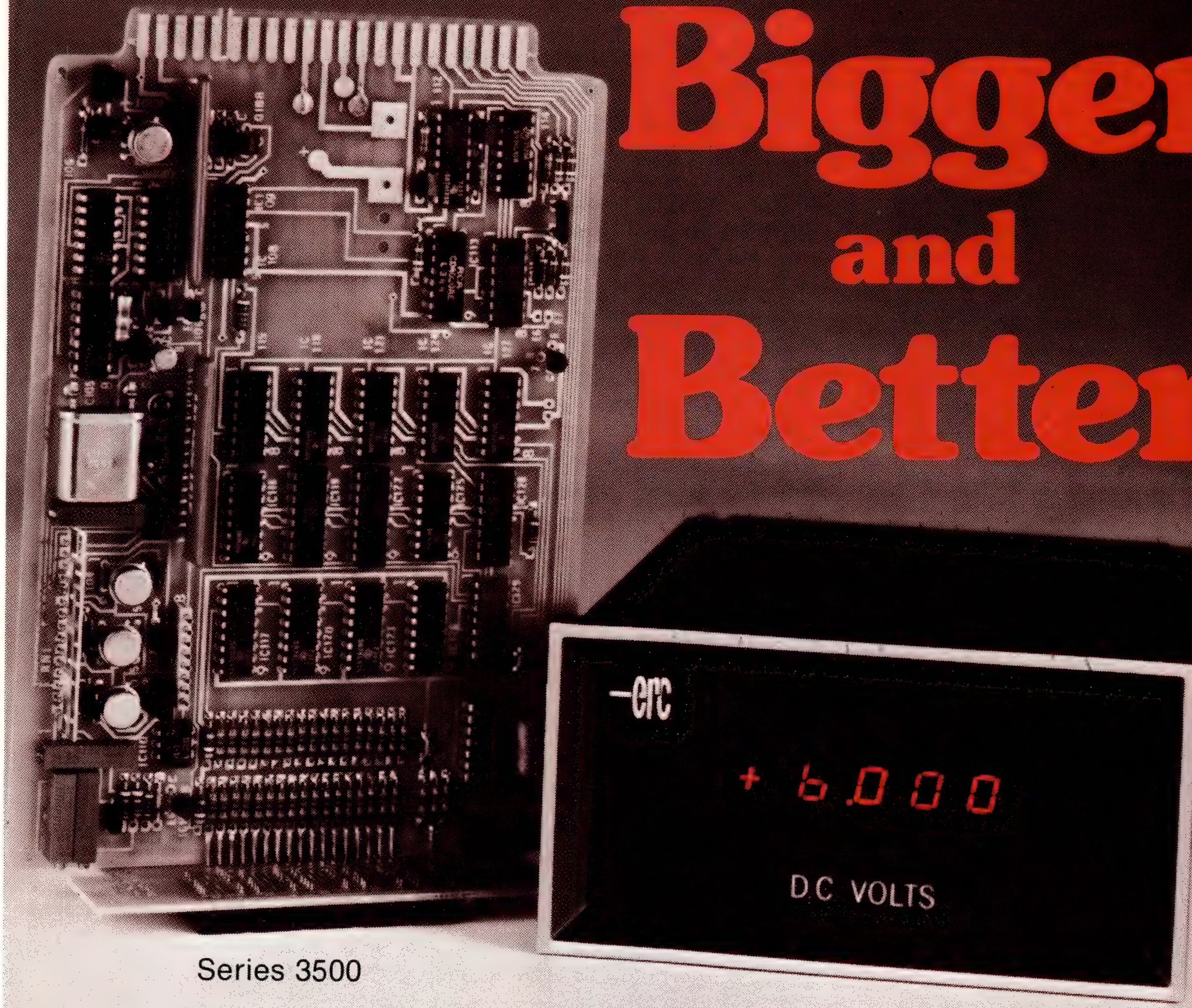

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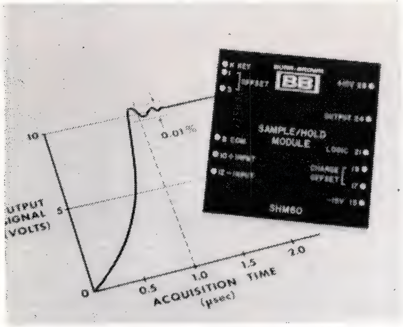
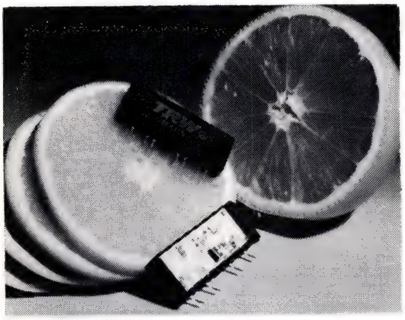


SAMPLE/HOLD MODULE FEATURES PROGRAMMABLE GAIN AND SPEED. The SHM60 acquires analog signals of up to ±10V amplitude, and settles to 0.01% in <1.5 μsec for 20V input step. Selectable gains range from unity to ±1000. Accuracy of 0.01% is guaranteed for a 1-μsec sample period, and for hold periods up to 15 μsec. $99. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. Phone(602)294-1431. **270**

MINIATURE POWER SUPPLIES MOUNT ON PC BOARDS. PCM-series supplies are designed for op amps, data converters and nonlinear circuits. They are complete with built-in overload and short-circuit protection. All 5V models have built-in overvoltage protection. Single-output models range from 50V at 500 mA to 24V at 50 mA. Dual-output models are available from ±12V at 120 to 400 mA and ±15V at 65 to 350 mA. Prices start at $25. ACDC Electronics, Inc., Oceanside Industrial Center, Oceanside, CA 92054. Phone(714)757-1880. **271**



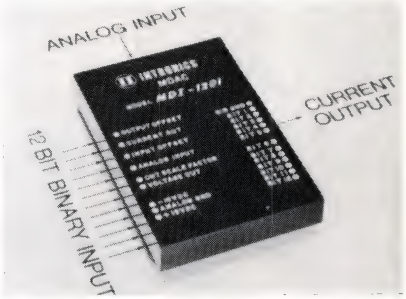
RF POWER MODULES DESIGNED FOR HANDHELD TRANSCEIVERS. MX1.5 modules operate in the 400-512 MHz range from a 7.5V battery. They provide 1.5W output, 20-dB gain and 50% efficiency. Input and output impedances are 50Ω. Full protection is provided against overdrive and load VSWR. $41.75. TRW Semiconductors, 14520 Aviation Blvd., Lawndale, CA 90260. Phone(213)679-4561. **272**

DC/DC CONVERTERS DELIVER FROM 0.9 TO 10W OF OUTPUT. Size ranges from 1.5×2.0×0.4-in. to 2.5×3.5×0.875-in. depending on type and output capacity. Standard output voltages are 5, ±12, ±15 and ±18V, with input ranges of 5, 12, 24 or 28V dc. Priced from $41.95 to $112.95, these units feature low output noise, 0.02% line and load regulation, and no derating through 71°C. Semiconductor Circuits, Inc., 306 River St., Haverhill, MA 01830. Phone(617)373-9104. **273**

VOLTAGE-TUNEABLE ACTIVE FILTER PROVIDES MULTIPLE OUTPUTS. Model 320VT has bandpass, band reject, lowpass and highpass outputs. Frequency can be set to any value from 0.1 Hz to 20 kHz. Voltage tuning range up to 20:1 can be externally set. Gain and Q are externally variable. $210. Frequency Devices, Inc., 25 Locust St., Haverhill, MA 01830. Phone(617)374-0761. **274**

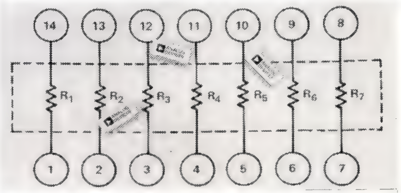
DC-DC CONVERTER OPERATES FROM MINICOMPUTER SUPPLY. This module allows noisy +5V minicomputer power supplies to operate ultra-precision analog circuitry through multiple isolation techniques. The DT15150 converts +5V to noise-free ±15V at 150 mA. The multiple input/output isolation has 80 pF effective capacitance, 1000 mΩ resistance, and >500V breakdown voltage. Efficiency is 65% min., and price is $109 (1-9). Data Translation Inc., 109 Concord St., Framingham, MA 01701. Phone (617)879-3595. **275**

INDUSTRIAL FREQUENCY SENSOR OFFERS 1% ACCURACY. Type HZA frequency-band sensor de-energizes electrical systems when the frequency of single or 3-phase service exceeds pre-set limits for a pre-set time. When frequency returns to normal, the sensor automatically re-energizes the system. Built-in time delays of up to 10 sec preclude nuisance tripping. Other specs include input operating voltage up to 600V and input frequency of 50, 60 or 400 Hz. Logitek, Inc., 42 Central Ave., Farmingdale, NY 11735. Phone(516)694-3080. **276**



MULTIPLYING DACS FEATURE FAST SETTLING TIME. Series MCI 1200 converters feature output settling times of 500 nsec, and a wideband (4 MHz) reference input. Monotonicity is guaranteed over the operating temp. range of 0 to 70°C. Units are completely internally trimmed. Two-quadrant operation is possible. $155 (MDI 1201), $125 (MDI 1202). Delivery is 6 wks. ARO. Intronics, Inc., 57 Chapel St., Newton, MA 02158. Phone(617)332-7350. **277**

D/A CONVERTERS COMBINE HIGH PERFORMANCE WITH LOW COST. Both series feature 5 μsec settling time. DAC-R models have 30 ppm/°C gain TC; DAC-TR have 5 ppm/°C. All models have 5 programmable output ranges. Input coding is complementary binary or offset binary. 8-, 10- and 12-bit models are available. $69-$79 (DAC-R), $129-$179 (DAC-TR). Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone(617)828-8000. **278**



PACKAGED THIN-FILM INDEPENDENT RESISTORS PRICED FROM $3. The AD1830 series of resistors may be selected with resistances ranging from 50Ω to 500 kΩ, ratio accuracies to ±0.01%, ratio TCR tracking to ±1 ppm/°C max., noise to −50 dB, response time <10 nsec max., and long-term ratio stability of 0.01%/yr at 25°C. Analog Devices, Box 280, Norwood, MA 02062. Phone(617)329-4700. **279**

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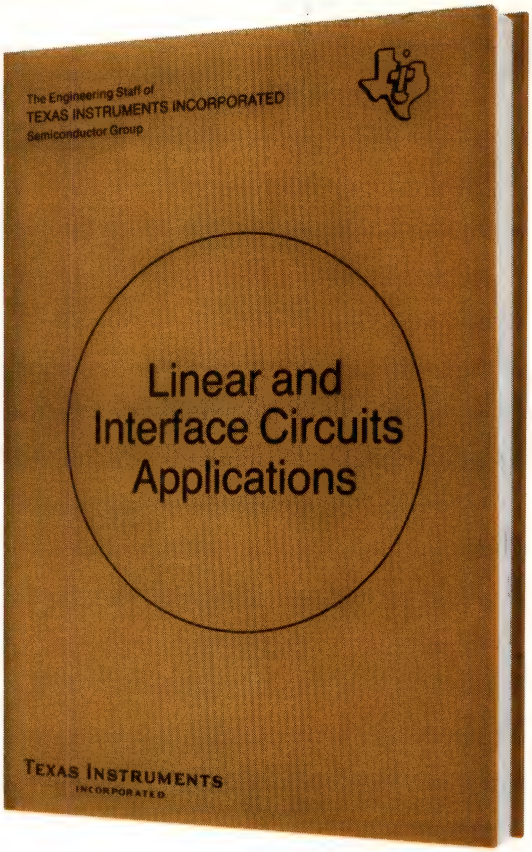
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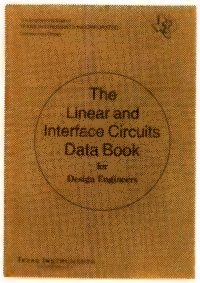
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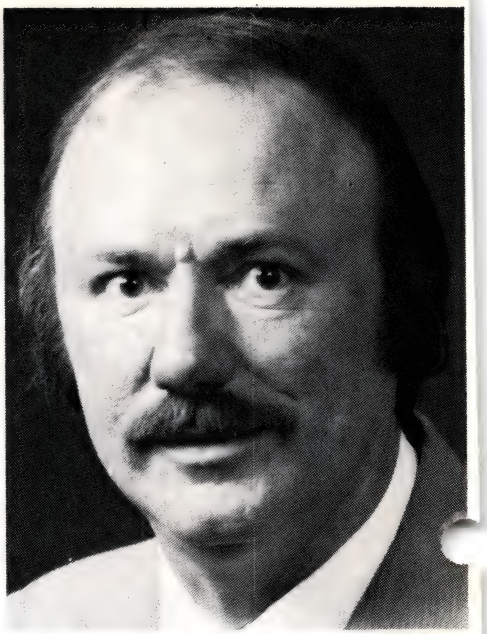

Jim Luksch, Executive Vice President
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Texscan is the world leader in its field. But we’ve found we may have grown complacent in telling you why.

Here briefly is just one comparison of our product versus competition.

The Wavetek 1801A and the Texscan WB-711 Sweep Generators are almost identical in specs. However, the Wavetek has 688 parts, Texscan 311. The Wavetek cost $1245. Texscan $870.

Take a look at the chart below. Fortunately for us, unfortunately for them; it’s only one of many examples:

	WAVETEK 1801A	TEXSCAN WB-711
Transistors	88	28
Resistors, Diodes, Capacitors and Inductors	598	294
IC’s	2	9
Total Parts	688	331
Price	$1245	$870

	Freq. Range	Pwr. Output	Dis- tortion	Flat- ness	Sweep Width	Sweep Rate	Linearity
Wavetek 1801A	1-500 MHz	0.7V RMS	−30 dB*	±0.35 dB	0.2−500 MHz	.01−50 Hz	2%
Texscan WB-711	1-500 MHz	0.7V RMS	−30 dB	±0.25 dB	0.1−500 MHz	0.5−60 Hz	2%

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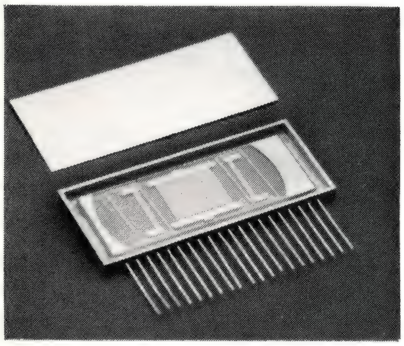


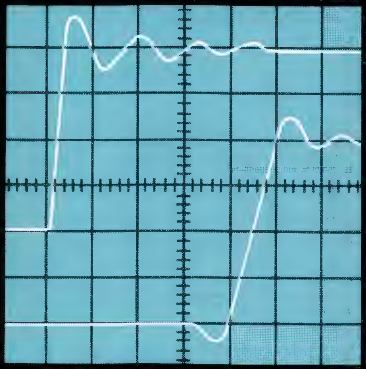
SURFACE ACOUSTIC-WAVE DELAY LINES HAVE MANY USES. Because of the unique surface energy characteristics of this type unit, the following are readily fabricated: linear delays, dispersive delays, phase-coded devices, tapped delay lines, linear-phase bandpass filters and system equalizers. Units can be built with temperature coefficients as low as 1 ppm/°C and with losses as low as 10 dB. Andersen Laboratories, Inc., Bloomfield, CT 06002. Phone(203)242-0761. **280**

2-GHz, MECHANICALLY-TUNABLE OSCILLATOR HAS LOW FM NOISE. Model FS-2137-1, a high-power, transistorized cavity oscillator with a ±0.1% AFC option may be mechanically tuned over any 200 MHz band between 1.5 and 2.0 GHz, with output power levels to 500 mW. AFC tuning sensitivity is typically 0.7 MHz/V over a ±0.1% bandwidth. Size is 2.5×1.0×1.25 in. Frequency Sources, Inc., 166 Middlesex St., North Chelmsford, MA 01863. Phone(617)251-8747. **281**

CASCADABLE FLATPACK AMPS SOLVE PACKAGING PROBLEMS. The new 0.5×0.38×0.125-in. flatpack is ideal for high-density packaging requirements. Frequency range is 5 to 500 MHz, with gain typically 14.5 dB. Noise figure is typically 4 dB for the WJ-A6 and 5 dB for the WJ-A8. Output power is +9 dBm for the WJ-A6, +14 dBm for the WJ-A8. $99 and $109, respectively (1-9). Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-4141. **282**

RESISTOR NETWORKS COME IN SINGLE IN-LINE PACKAGES. Produced by high speed, computer-controlled laser trimming, the networks feature resistor tolerances to 0.01% at low cost in quantities. All exhibit the stability, tight temperature-tracking and low-noise properties inherent in thin metal film designs. Standard networks are available off-the-shelf in 6-, 8- or 9-pin packages. LRC, Inc., 1001 Digital Dr., Hudson, NH 03051. Phone(603)883-9351. **283**

12-BIT DAC'S COME IN 16- AND 18-PIN DIP'S. The current-output DAC345I and its companion voltage-output DAC346V are claimed to be the first complete IC-sized D/A converters available with true 12-bit linearity and drift. Both units are complete with internal reference, ladder and switches. The voltage version includes the output amplifier with its pretrimmed feedback resistors. Settling time (0.01%) is 1 µsec max. for the current DAC, 15 µsec for the voltage one. Hybrid Systems Corp., 87 Second Ave., Burlington, MA 01803. Phone(617)272-1522. **284**



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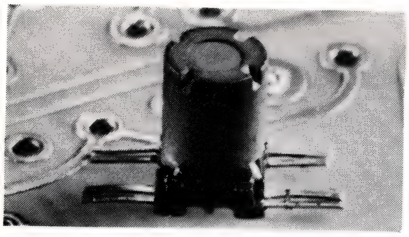
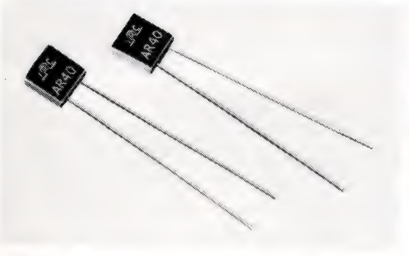
COMPONENTS/ MATERIALS

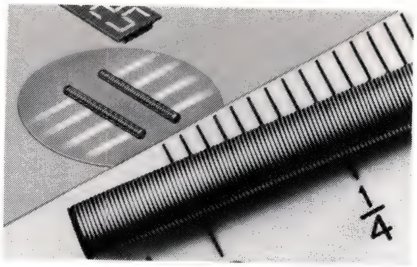


MINIATURE ADJUSTABLE-INDUCTANCE COILS BOAST HIGH "Q." With body diameter of only 0.185-in. and height of 0.21 to 0.25-in., Series SV2 inductors have typical Q of 100 at 1 to 25 MHz. Nominal inductance values range from 0.1 to 1000 μH. The magnetically-shielded inductors use a threaded cup for inductance variation—typically by as much as ±30% around nominal. They are available for immediate delivery from SAE's national distributors. Stanford Applied Engineering, Inc., 340 Martin Ave., Santa Clara, CA 95050. Phone(408)243-9200. **182**

RESISTOR SYSTEM IS CALIBRATED FOR 2 FIRING TEMPERATURES. #2800 thick-film resistor ink formulations are now offered, if specified, calibrated to 850°C firing. Sheet resistivity from 10Ω to 10 kΩ/sq will be supplied with TC of 100 ppm/°C or less. The 10 kΩ and 1 MΩ/sq inks will have TCR's similar to the 780°C firing material. A new range, 5Ω/sq, is also available. For improved-TCR inks add $1/gram. There is no price increase for standard-TCR pastes calibrated at 850°C. Electro-Science Laboratories, Inc., 1601 Sherman Ave., Pennsauken, NJ 08110. Phone(609)663-7777. **183**



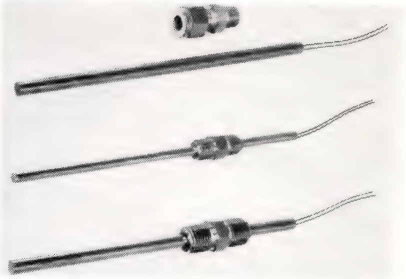
ULTRA-PRECISION METAL-FILM RESISTORS PROVIDE LOW NOISE. Designated AR40, they offer a low TC and excellent high-frequency performance. The construction employs 2 elements welded together and housed in an epoxy case measuring 0.32x0.295x0.1 in. The available resistance range is 20Ω to 100 kΩ with standard tolerances to 0.01% and TC of ±2 ppm/°C. Power rating is 0.3W at 85°C. Typical price for a 0.05%, 2 ppm/°C unit is $2.40(1000). TRW/IRC Resistors, Box 887, Burlington, IA 52601. Phone(319)754-8491. **184**



ELASTOMERIC CONNECTOR OPERATES ON PRESSURE ALONE. A non-conducting elastomeric core is wrapped with parallel lines of gold-plated conductors on thin, flexible film. When compressed between parallel planes, the lines interconnect the circuitry with assured contact redundancy. Typical pad-to-pad performance characteristics with liquid-crystal displays are: contact resistance of 150 mΩ' contact rating of 500 mA and min. insulation resistance of 300 MΩ. AMP Inc., Harrisburg, PA 17105. Phone(717)564-0101. **185**

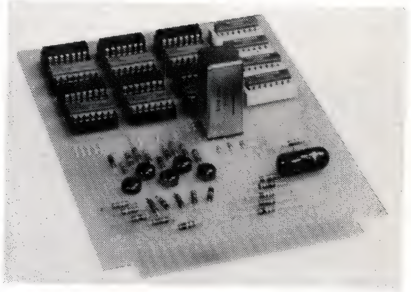
LIGHTED PUSHBUTTON SWITCHES HAVE DPDT ACTION. S190-series is available with either momentary or alternate action. The dual wiping contacts are rated at 100,000 cycles at 2A and 250,000 cycles at 100 mA, resistive. Silver-inlay terminals accept either two #22 AWG soldered wires or 0.110-in. quick-connect receptacles. Molded parts are SE-O thermoplastic, and mounting is either rear panel or snap in. Clare-Pendar Co., Box 785, Post Falls, ID 83854. Phone(208)773-4541. **186**

ADDED 5/8-IN. KEYBOARD SWITCH CAPS TRIPLE THE PRODUCT LINE. Caps are now available for both single and double-button OAK Series-415 keyboard switches, in flat, square-raised and round-raised styles, with 287 numeric and special characters. These switches offer operating life of 10 million operations, and function in temperatures from −20 to +75°C. White, black, red, blue and gray caps are available. Switch cost is under 20¢ ea in production quantities. Delivery is about 6 wks. ARO. Oak Industries Inc., Switch Div., Crystal Lake, IL 60014. Phone(815)459-5000. **187**



HIGH-PRECISION PLATINUM RTD'S ARE INTERCHANGEABLE. Ultra-Therm^R resistance temperature detector probes are available in a broad variety of ranges and mounting configurations. They can be used for sensing temperatures from −200 to +500°C, and are available in cartridge, threaded-fitting and spring-loaded types. The T.C. of these 100Ω sensors is 0.00385Ω/Ω/°C. Tolerances are ±0.1% to ±1.0%. $15, up. Thermalogic, 241 Crescent St., Waltham, MA 02154. Phone(617)891-9496. **188**

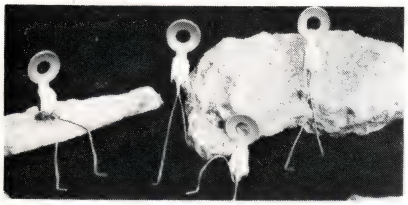
HEAT EXCHANGER PROVIDES DUST-FREE CABINET COOLING. The Model 5001 filterless heat exchanger measures 19×12×8-1/2-in. and operates on 115V, 60 Hz, 1 phase. It accommodates a rated cooling load of 650W and delivers 250 ft.^{3}/min. of cool, clean air. There are no filters to clog or replace. The air inside the cabinet is continuously recirculated, so no dust or dirt enters the system. Astro Dynamics, Inc. Second Ave., Burlington, MA 01803. Phone(617)272-3900. **189**



VERTICAL MERCURY-WETTED REED RELAY SAVES PC-BOARD SPACE. These devices require <1/2-in.^{2} of board surface and are only 1.37-in. high. They are magnetically shielded, and feature insulation resistance of $10^{10}\Omega$ and min. breakdown voltage of 1000V dc. Contact ratings include 1A dc max., 100V dc max., 0.05Ω max. initial contact resistance and 28W max. power limitation. Coil voltages from 5 to 24V and 1A, 2A or 2B contacts are offered. From $4.60 (100). Electronic Instrument & Specialty Corp., 42 Pleasant St., Stoneham, MA 02180. Phone(617)438-5300. **190**

INDUSTRIAL BONDING LIQUID SETS IN <1 MIN. Zipbond contact cement bonds most materials almost instantly. No pre-mixing is necessary. You use the liquid directly from the 1-oz squeeze applicator bottle or from a production-line dispenser. No heat or pressure treatments are required. Zipbond is impervious to most chemicals, weather and temperatures. Its low viscosity allows it to seep into tiny spaces. One drop covers a 1-in.^{2} area to form a colorless transparent bond. Tescom Corp., 2600 Niagara Lane N., Minneapolis, MN 55441. Phone(612)546-4351. **191**

FREE SAMPLE PART SHOWS CLAD PRECIOUS-METAL CAPABILITY. An actual part, this provides the connection for flash and shutter applications in a camera. Technical Materials, Inc. furnished coiled clads from which the stampings were made. The 2-part connector uses beryllium copper as a base metal. The dimpled ends have an 18-karat gold edgelay and solder stripes are visible on both sides of the terminals on the other end. Technical Materials, Inc., 25 Holden St., Providence, RI 02908. Phone(401)272-4343. **192**



SEMICONDUCTOR PROTECTOR SENSES CASE TEMPERATURE. Called a Posistor^R, the PTH 487A is mechanically affixed to the semiconductor case and electrically connected in series with the base-biasing circuit in typical applications. Resistance is nominally 500Ω, increasing to 2000Ω at 176°F and 3000Ω at 194°F. Max. voltage and current ratings are 12.5V dc and 0.1A, respectively. Murata Corp. of America, 2 Westchester Plaza, Elmsford, NY 10523. Phone (941)592-9180. **193**

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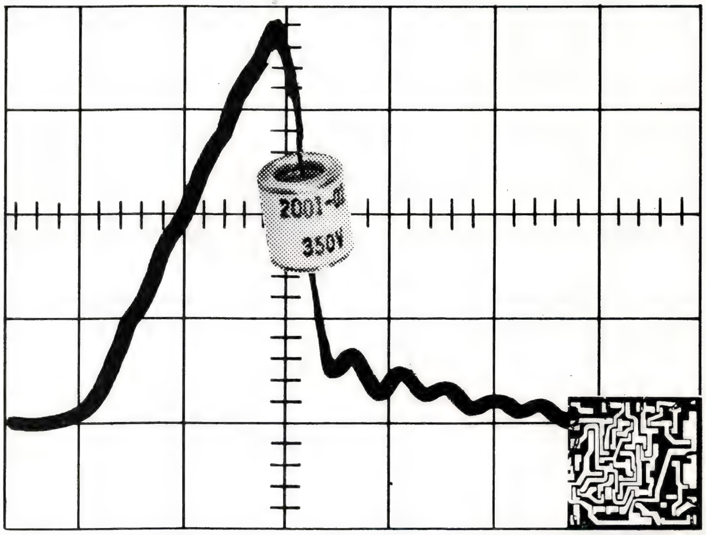

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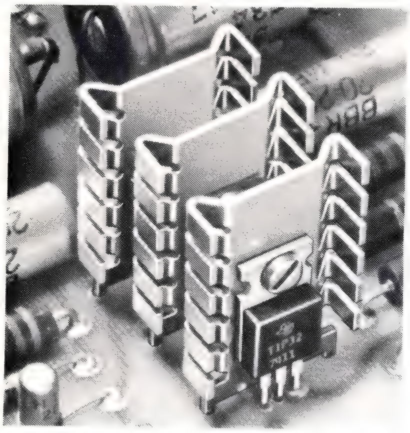
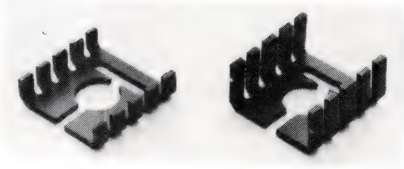
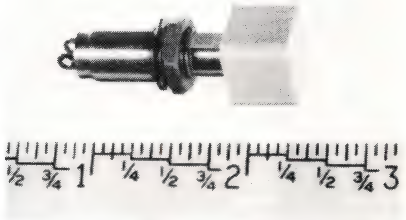


HEAT DISSIPATOR BOOSTS RATING OF POWER PLASTIC TRANSISTORS. In natural convection, the PSB2-1ND permits operation at power levels 2-1/2 times greater than with bare-case devices. At 200 fpm, power levels can be increased 5 times and at 1000 fpm, 13 times. The dissipator requires only 1/4×7/8-in. of board space. Mounting feet insert into the pc board and both transistor and dissipator are soldered simultaneously. 17¢(1000). International Electronic Research Corp., 135 W. Magnolia, Burbank, CA 91502. Phone(213)849-2481. **194**

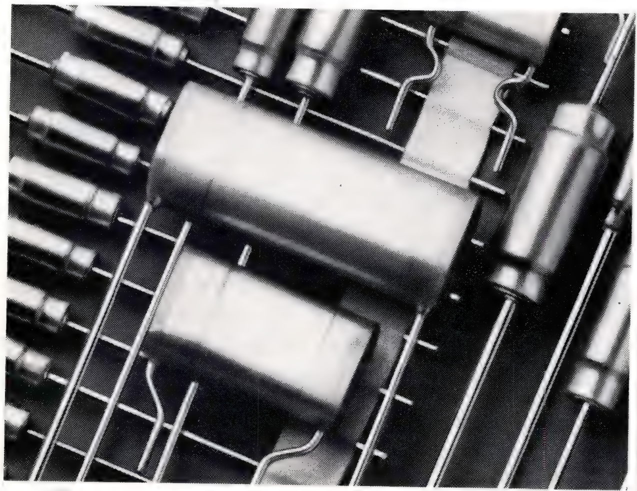
METRIC, HIGH DENSITY WIRE-WRAPPING PANELS ARE OFFERED. The 3 metric panels measure 100×160 mm and contain 2-piece machined contact assemblies. Of 1/16-in. double-sided glass epoxy, they have voltage and ground planes connected to wire-wrapping socket terminals. Panels 8136-MG16 and -MG17 have voltage and ground pins located in each pattern, while the -UMG2 has both located at preselected positions adjacent to I.C. rows. $40 to $90. Augat Inc., 33 Perry Ave., Attleboro, MA 02703. Phone (617)222-2202. **195**



FINNED HEAT SINKS FOR TO-5 CASES PUSH ON. This design allows the entire heat-sink-to-case contact area to be placed at the case flange, the area of max. thermal emission. There are 2 models: 1134, with fins 0.187-in. high and weighing 0.0024 lb.; and 1136, with fins 0.375-in. high and weighing 0.0032 lb. They are available unfinished, black anodized or with gold-chromate finish. Model 1134-U, 5¢(1000). Thermalloy, Box 34829, Dallas, TX 75234. Phone(214)243-4321. **196**



MINIATURE PB SWITCH HAS HI-REL SNAP-ACTING MECHANISM. Incorporating a mil-approved basic switch mechanism, the pushbutton B9100 switches provide a wide range of electrical ratings to 7A resistive in an unusually small package. Their plunger travel and operating force deters accidental operation. The line includes moistureproof or unsealed versions with single pole, N.O. or N.C. configurations. Control Switch, Inc., 1420 Delmar Dr., Folcroft, PA 19032. Phone(215)586-7500. **197**



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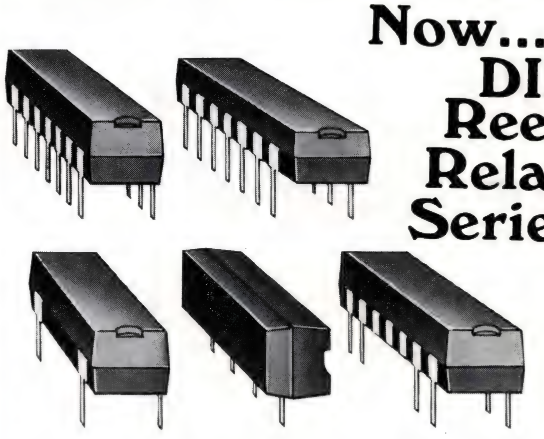

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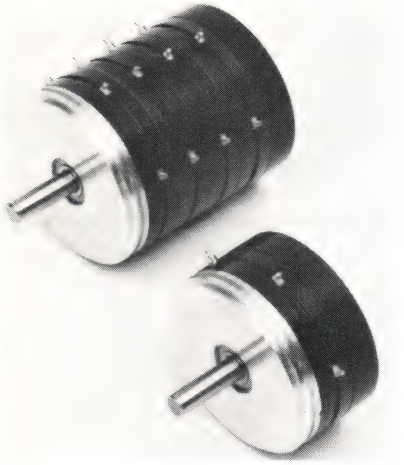

PRECISION POTS FEATURE LONG LIFE, UNLIMITED GANGING. Series TTL units feature ball-bearing servo or threaded-bushing mount, high accuracy, infinite resolution, linear and nonlinear outputs to suit and multiple-fingered wipers to yield 20,000,000-cycle life. They are available in 1-3/32-in. and 2-in. case diameters, from stock, in a wide variety of resistances and linearities. Computer Instruments Corp., 92 Madison Ave., Hempstead, NY 11550. Phone(516)483-8200. **198**

SELF-REGULATING OVEN FITS SHORT-LEAD TO-5 DEVICES. The 4ST2 was designed for use where lead lengths are restricted to 0.5-in. Devices having up to 8 leads are readily installed without special tools. Ovens with control temperatures of 65, 80 and 115° C are available (they operate in ambients from −50°C up to 50, 60 and 100°C, respectively). A semiconductor heater provides the infinitely-proportional control. Power required is 24±4V ac/dc, 0.6W (at 25°C ambient). Jermyn, 712 Montgomery St., San Francisco, CA 94111. Phone(415)362-7431 **199**

ROCKER SWITCHES FEATURE SNAP-IN MOUNTING. Available in illuminated and non-illuminated versions and with ac-dc versatility to 20A, they are offered with bezels or for sub-panel mounting. Illuminated switches are offered with red, green, amber or clear rockers and various bulbs. Colors for non-illuminated rockers are white, blue, gray, red or black. Standard features of the 1 and 2-pole, double-throw rocker switches include solder lug, spade and screw terminals, silver-plated contacts and slow-make, slow-break operation. From 40¢ to $1. Cutler-Hammer, Inc., 4201 N. 27th St., Milwaukee, WI 53216. Phone(414)442-7800. **200**

16-POSITION STRIPSWITCHES MOUNT BY WAVE SOLDERING. Both small and inexpensive, they are well suited for programming computers and using computer-type logic where 16-bit words are the basic logic information unit. The switches are one-piece molded units with up to 6 switch stations/strip. Models are available for screw-driver, finger-tip or knob setting. Under $1 in production quantities, with delivery in 16 wks. Electronic Engineering Co. of California, 1441 E. Chestnut Ave., Santa Ana, CA 92701. Phone(714)835-6000. **201**

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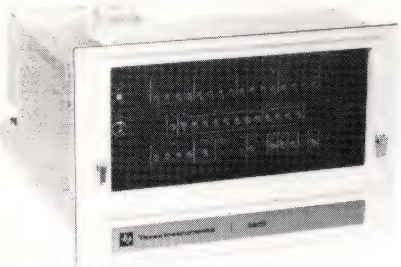


MINI PACKS UP TO 24k 16-BIT WORDS ON 1 MOS MEMORY BOARD. These memories use 4k RAM's and feature bit-error detection/correction, along with instant visual fault isolation, programmable protection and privileged instructions. The rack-mounted Model 980B general-purpose minicomputer also features 8k words of memory with 750 nsec cycle time, and 8 directly-addressable registers. It uses 98 basic instructions (16, 32 or 48 bits) with auto-restart and is configured for Fortran and Basic. A DS330 disc interface is included as an option. $4975. Texas Instruments, Inc., Box 2909, Austin, TX 78767. Phone(512)258-5121. **170**

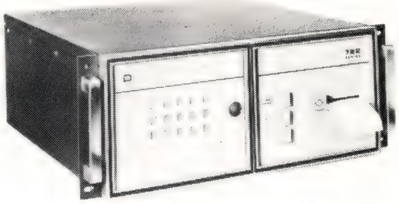
SERIAL-IMPACT PRINTER FOR PROGRAMMABLE CALCULATOR. The PRINTEC-100 serial-impact printer, that interfaces the H-P 9830A, prints full typewriter-like characters at 35-100 lpm rates. Adjustable tractors enable the printer to handle any paper width from 4 to 14-7/8 in. Deliveries are 30 days ARO. $3145. Printer Technology, Inc., Sixth Rd., Woburn Industrial Park, Woburn, MA 01801. Phone(617)935-4246. **171**

12-IN. MONITOR HAS 100% SOLID-STATE CONSTRUCTION. Video monitor Model MV-12, provides >650-line resolution and features plug-in modules with front mounted controls and adjustments. An external sync is available in Model MV-12-EX. The monitor can be used for data terminal display, security-surveillance applications, and broadcast, educational, industrial, studio, medical and VTR display. GBC Closed Circuit TV Corp., 74 Fifth Ave., New York, NY 10011. Phone(212)989-4433. **172**

FIXED-HEAD MEMORY OFFERS 150k BITS/TRACK AT 3600 RPM. This fast disc has a capacity of 19.2 Mbits. Offering an average access time of 8.3 msec with a data-transfer rate of 9 MHz, the memory system is capable of field expansion in 16-track increments up to 128 tracks. Error rate is <1 in 10^{12} bits. Options are available. The system mounts in a 14-3/4×17×19-in. rack and is available for either 50- or 60-Hz operation at 120V, at 50 to 115°F. Under $10,000. Pacific Micronetics Inc., 5037 Ruffner St., San Diego, CA 92111. Phone(714)279-7500. **173**

ELECTROSTATIC PROOF PRINTING IS AT 200 DOTS/IN. Two models print hard proof copy at 132 characters/line, 12.5 characters/in., and 8 lines/in. Both use 11-in. paper, roll or fanfold. The Matrix 1250 P proofer is linked to computer with controller interface for on-line systems, printing at 1100 cps. 38×19×18 in. 160 lbs. $8200. The Matrix 1250 PTR proofer system combines proofer and paper-tape reader to form an off-line system for ASCII or TTS paper tape input, printing at 500 cps. 38×27×18 in. 180 lbs. $10,000. Versatec, 10100 Bubb Rd., Cupertino, CA 95014. Phone(408)257-9900. **174**

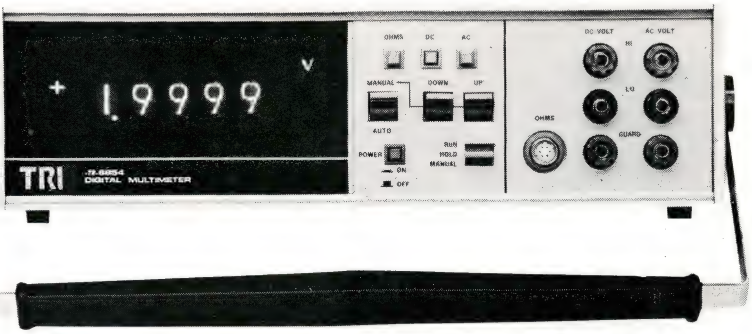
TIMESHARING GRAPHICS OFFERS COST/PERFORMANCE CHOICE. This BP-734 timeshare/Serial Graphics Interface plots 256 or 1024 vectors on any scope or x-y display. No modification to terminal or scope is needed, just select the baud rate and run. Vector update speed is 5/sec with 30 cps terminal or 40/sec with a high-speed line at 2400 baud. Megaplot, a Fortran or Basic callable subroutine, is supplied. 8-bit and 10-bit versions are priced at $1595 and $2495, respectively. Megatek Corp., 1055 Shafter St., San Diego, CA 92106. Phone(714)224-2721. **175**



HIGH-SPEED DIGITAL PRINTER HANDLES UP TO 22 CHAR./LINE. Series 722 printers are available in either hexidecimal or alphanumeric versions and with thruput up to 2760 cps. The input is either character parallel or character serial. Each unit measures 16-3/4×17-3/4×7 in. and weighs 75 lbs. $990 for the print mechanism and $4500 for the complete high-speed printing system. Datadyne Corp., Box 247, King of Prussia, PA 19406. Phone(215)265-1793. **176**

SOFTWARE BOOSTS CAPABILITIES OF MODCOMP COMPUTER SYSTEMS. MAX II/III operating systems are designed for real-time multiprogramming. The latest user-oriented revisions provide a greater flexibility of operator communications using priority levels. The I/O system (handlers) was revised. Tasks now available are SPOOLER and terminal emulators. "Round-robin" task execution at priority level and better memory utilization through (15) core partitions plus multi-level checkpointing are included. Modular Computer Systems, Inc., 1650 W. McNab Rd., Ft. Lauderdale, FL 33309. Phone(305)974-1380. **177**

OPTIONAL PRINTER FOR CRT ANNUNCIATION. The Model 120 printer functions as a conventional sequential events recorder. However, CRT or backlighted display can be added for primary or back-up annunciation. The printer has an event memory and will record up to 65 events in actual sequence with msec resolution. Options include 22-character English language printout on the sequential events recorder, clock and calendar. The Riley Co., 7405 N. Hamlin Ave., Skokie, IL 60076. Phone(312)675-2500. **178**



OVERDESIGNED.

Over designed, yet nicely designed. T.R.I. offers three digital multimeters for three distinct needs (and *all* have automatic ranging as a standard feature):

1. A 3½ digit DMM for the production line. The 6354 achieves 0.1% DC and 0.5% AC accuracy to 20 kHz, with a 6 month calibration guarantee. It has a speed of 2.5 samples/second (or 6/sec. as an option). With shunt, DC amps range from 20μA to 2A. Price: $289.

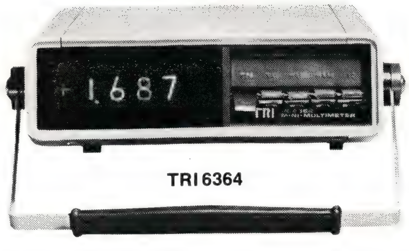
2. A portable 4 digit DMM for service engineers. The 6364 is accurate to 0.01% DC, and to 0.03% AC. It is stable to 0.02% for 180 days. And is optionally available with a rechargeable battery pack plus carrying case. The 6364 sells for $495.

3. The 6854 is our 4½ digit DMM intended for the laboratory. It's small, (8.6 lbs.) and it's extremely accurate: 0.008% of RDG ±0.01% F.S. on 20 mV DC range or, 0.02% of RDG ±0.04% of F.S. ±1 digit on 100 Hz to 10 kHz (AC). Frequency range is 45 Hz to 100 kHz at AC. Stability is 0.015% of RDG on 200mV/2V/20V, and this is guaranteed for 6 months. its autoranging capability goes to 20000 on the up-level; and to 01800 on the down-level. It has a full-bit-serial BCD output; a noise-rejection CMR (DC) of 140 dB and a NMR of 40 dB. It costs $689.

Three DMMs. Three purposes. Three prices. Give us a call, or write today.

FROM ANY POINT OF VIEW.

TRI 6854


TRI 6364

TRI 6354

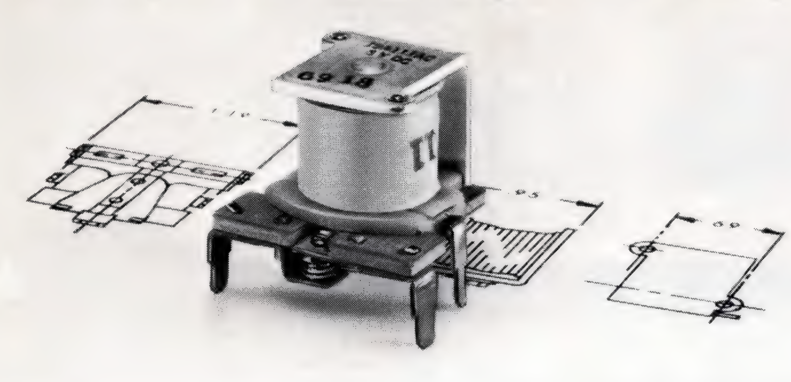
TRI

T.R.I. CORPORATION
505 West Olive Avenue • Sunnyvale, CA. 94086 • (408) 733-9080

P.S. We also have a 5½ digit DMM (model 6656) and a 6½ digit DVM (model 6567).

Circle No. 56

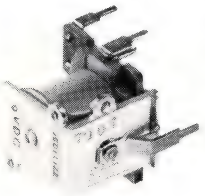
10 amps of switching in a 1″cube!



We call it our Series 19 Relay. You'll call it one of the most compact and reliable packages you've ever used.

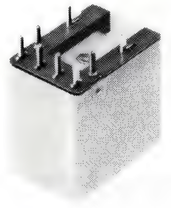
Remarkable 10 amp Series 19 relay is low in cost, too — less than $1.00 each in quantity. But price is only part of the story. The Series 19 also offers the advantages of miniaturization and the capacity to handle heavy switching loads. Result: more performance in a smaller overall package. Contact arrangement is SPDT. Rated 10 amps at 28 vdc or 115 v, 60 hz. Coil voltages available range from 3 to 24 vdc. The Series 19 is an ideal choice for a multitude of low level to 10 amp switching applications, including remote control, alarm systems and many other industrial and commercial uses.

Equally important, the Series 19 is part of a whole family of interrelated low-cost relays which will lend themselves to multiple usage in the same system. Included are:

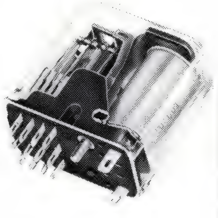


Series 10. Sensitive, low cost, highly reliable SPDT relay rated at 3 amps, 28 vdc. Coil voltages 3-24 vdc. Can be used for a wide range of industrial and commercial control functions and alarm systems.

Series 28. Same as Series 10, but furnished with a dust cover for use in appliance controls, remote TV tuning, industrial process controls and similar functions.



Series 38. DPDT, 3 amp 28 vdc contacts. Coil ratings 3-24 vdc. Applications include business machine controls, antenna rotor controls, industrial process controls, etc.



GP. A miniature general purpose relay with 2, 4, or 6 PDT contacts, rated 1, 2 or 5 amps, 28 vdc or 115 v, 60 hz. Coil voltages: 6-115 vdc. Consider the GP for copiers, business machines, control or alarm systems, etc. Available with single or bifurcated contacts.

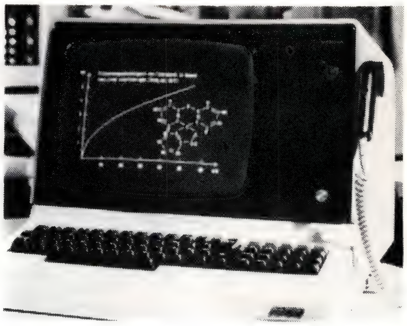
Send for information. Complete technical data on NAPCC relays available on request. Write today.

NORTH AMERICAN PHILIPS CONTROLS CORP.

Frederick, Md. 21701 · (301) 663-5141

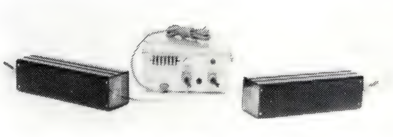
Circle No. 57

COMPUTER PRODUCTS



DATA TERMINAL ADDS DIACRITICS TO GRAPHICS IN DISPLAY. Diacritics (i.e.Å) can be added to the 95 alphanumerical characters used in combination with graphics for inscriptions on coordinate axes and curves. Developed for remote data processing, the video terminal has a capacity of 1296 characters on a printing area of 14.5×22 cm. Screen contents can be emphasized optically by flashing or italics. The Transdata 8152 terminal conforms to CCITT recommendations V 24 and V 28 and, teamed up with modems, can operate on automatic telephone networks. Siemens Corp., 186 Wood Ave. S., Iselin, NJ 08830. Phone(201)494-1000. **179**

MINI-CALCULATOR BOASTS 10-DIGIT CAPACITY. It weighs only 9 oz. and measures 3-1/16×5-7/16×1-1/2 in. Versatile, the LE-100 solves add-on and discount calculations, mixed calculations, chain multiplication and division. It features all-floating decimal point, zero suppression, overflow indicator, minus indicator and automatic constant. There is a choice of 3 different power sources; 4 penlight batteries, rechargeable Nicad battery pack, or ac Palmtronic Charger II. $99.95. Canon U.S.A., Inc., 10 Nevada Dr., Lake Success, NY 11040. Phone(516)488-6701. **180**



OPTICAL DATA LINK SUITS INDOOR NEEDS. This high speed, digital communications link uses an injection laser to transmit asynchronous data at rates to 9600 bps over indoor paths up to 3000 ft long. Four models are offered in the DL-100 series. Two feature a voice channel, which is multiplexed with the data on a single carrier. The terminals will interface with TTY or RS-232-C. Delivery in 4 mo. $7200. International Laser Systems, Inc., 2111 West Central Blvd., Orlando, FL 32805. Phone(305)843-4731. **181**

MARK TEN B, THE GAS SAVING, PLUG SAVING, TUNE-UP SAVING, ELECTRONIC IGNITION FROM DELTA. NOW AS LOW AS $49.95.

Years of testing and use by race car drivers in all categories have proven Delta's Mark Ten B the most advanced ignition system on the market today.

Prove it to yourself. Give you car vroooom! With a Mark Ten B Capacitive Discharge Ignition System under the hood of your car great things will happen... like reducing costly tune-ups by as much as 75%. Further, you get better all-weather starts, quicker acceleration and better mileage.

Many operational problems caused by emission control devices, poor manifolding or improper fuel mixtures disappear. Delta's Mark Ten B even improves the performance of brand-new factory installed electronic ignitions (Chrysler and Ford). Factory systems merely eliminate points and condenser, but the Delta Mark Ten B combines the advantages of capacitive discharge with solid state electronics to give real performance and increased energy.

Are you a do-it-yourselfer? Build your own Mark Ten B... it's available in low-cost kit form. Or, if you prefer, get the complete ready-to-install unit. Either way, you can install it yourself in minutes with no rewiring, even over Chrysler and Ford systems.

Mail the coupon today and discover how to enjoy happy motoring with Delta's Mark Ten B. The do-it-yourselfer's dream that really pays off.

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303-242-9000

☐ Please send me free literature.
Enclosed is $________ ☐ Ship ppd. ☐ Ship C.O.D. Please send: ________ Mark Ten B assembled @ $64.95 ppd. ________ Mark Ten B Kit @ $49.95 ppd. (12 volt negative ground only) ________ Standard Mark Ten assembled, @ $49.95 ppd. ________ 6 Volt: Neg. Ground Only ________ 12 Volt: Specify ________ Pos. Ground ________ Neg. Ground ________ Standard Mark Ten Deltakit® @ $34.95 ppd. (12 Volt Positive or Negative Ground Only)

Car Year ________ Make ________

Name ________

Address ________

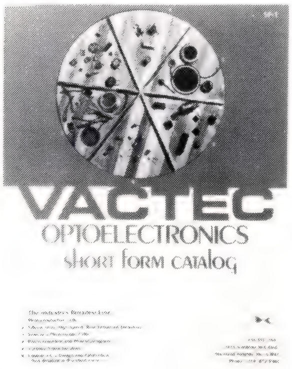
City/State ________ Zip ________

Circle No. 58

HP'S COMPUTER PRODUCTS. A 26-pg. catalog contains photos and descriptions of more than 100 OEM products. Included are the 21MX Series minis with SC memory, and the HP 2100 Series minis and minicomputer systems, all with microprogramming options. Peripherals include plotters, magnetic-tape and disc subsystems, printers and readers. It also describes I/O extenders, interfaces and software. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. **202**

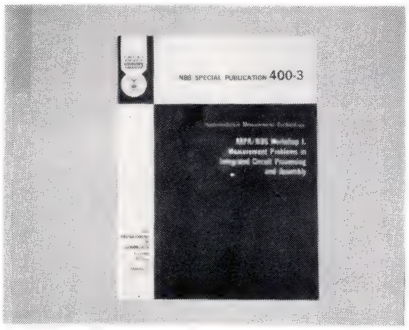
STRAIN GAGES. Illustrated and indexed to provide quick reference, this 87-pg. catalog covers commonly-used foil and wire strain gages, semiconductor gages, solid state sensors and accessories. BLH Electronics, INC., 42 Fourth Ave., Waltham, MA 02154. **203**

CONTACTS AND RELAYS, their contact protection and arc suppression, is the subject of app note, AN-1005. This 8-pg. article discusses a full range of protective devices, dielectric breakdown, selenium suppressors, and relay circuits without spark suppression. International Rectifier Corp., 233 Kansas St., El Segundo, CA 90245. **204**



OPTOELECTRONICS. Catalog SF-1 gives specs, part numbers and dimension drawings on CdS and CdSe photoconductive cells; silicon solar cells; silicon low-capacitance detectors; silicon blue-enhanced cells; selenium photovoltaic cells; npn phototransistors and photodarlingtons; and Vactrol opto-isolators. Vactec, Inc., 2423 Northline Industrial Blvd., Maryland Heights, MO 63043. **205**

NAT'L/INTERNAT'L STANDARDS. More than 5600 American National Standards and 3000 international standards and recommendations are listed in this 176-pg. 1974 catalog. Dimensions, ratings, terminology and symbols, test methods, and performance and safety requirements for 26 technical fields are covered. Also included is a list of special ANSI publications in the field of standardization. American National Standards Institute, 1430 Broadway, New York, NY 10018. **206**



IC'S. NBS publication 400-3 deals with IC processing and assembly. Particular attention is given to measurement problems in silicon, oxides, photolithography and assembly and the problems in information dissemination. 69¢ ea. U.S. Government Printing Office, Washington, DC 20402. **INQUIRE DIRECT.**

OPTO-ISOLATORS. The 6-pg. brochure introduces Vactrols—axial opto-isolators which operate with either incandescent or neon lamps and have photoconductive-cell output. Included are technical notes, dimension drawings and 40 graphs. Vactec, Inc., 2423 Northline Industrial Blvd., Maryland Heights, MO 63043. **207**

THERMISTOR CALCULATOR. Key features of the thermistor slide-rule calculator allow users to determine max. power or voltage for desired min. temperature error in design of temperature control and measurement circuits; resistance ranges at 25°C; dissipation and time constant for special thermistor types; max. operating temperature, and thermistor resistance at any temperature point. Fenwal Electronics, 63 Fountain St., Framingham, MA 01701. **208**

AEROSOL PRODUCTS. This short-form catalog describes available aerosols, and depicts, with line drawings, their application. A chart lists the equipment to be maintained, the cleaning problem, the remedy and the aerosol product to solve that problem. Miller-Stephenson Chemical Co., Box 628, Danbury, CT 06810. **209**

IC PARAMETER EVALUATION. Three app notes describe how the J127 circuit analyzer can be used to evaluate I_{CC}, V_{OL} and input threshold. Each note shows a sample programming worksheet, and includes an illustration of the gate under test. Teradyne, Inc., 183 Essex St., Boston, MA 02111. **210**

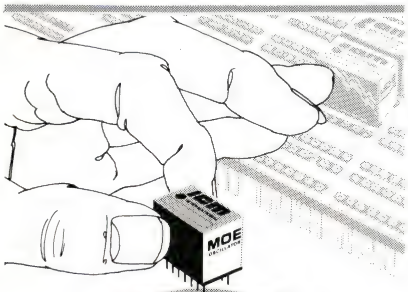
ANALOG MODULES. The 136-pg. applications book "Applications of OEI Products" has 3 indexes and is broken down into 8 general product categories. Coverage includes op amps, A/D converters, logarithmic amplifiers, V/F converters, active filters and analog memories. Price is $5. Optical Electronics, Inc., Box 11140, Tucson, AZ 85734. **INQUIRE DIRECT.**

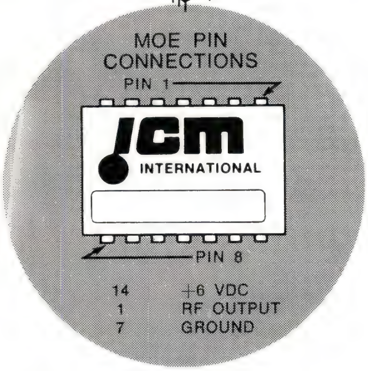
ELECTRONIC TEST ACCESSORIES. New products introduced in this general catalog include a "Grabber" test probe, a 36 kV test probe, 7 adapters, 3 banana jacks with wire-wrap terminals, 4 patch cords and 1 molded breakout. Illustrations and complete engineering information on all products are provided. Pomona Electronics, 1500 E. Ninth St., Pomona CA 91766. **211**

INTERNATIONAL'S

MOE crystal oscillator

elements provide a complete controlled signal source from 6000 KHz to 60 MHz





The MOE series is designed for direct plug-in to a standard dip socket. The miniature oscillator element in a complete source, crystal controlled, in an integrated circuit 14 pin dual-in-line package with a height of .6 inches, width .5 inches and length .8 inches.
Oscillators are grouped by frequency and temperature stability thus giving the user a selection of the overall accuracy desired. Operating voltage 6 vdc.

SPECIFICATIONS

DC Input	6 VDC @ 10ma max
RF Output	–10 bdm (periodic)
Output Impedance	Low, 100 ohms
Freq. Stability	MOE–5 ±.002%
(–10°C to +60°C)	MOE–10 ±.0005%
Calibration	±1ppm at 25°C

TYPE	CRYSTAL RANGE	OVERALL ACCURACY	25°C TOLERANCE	PRICE
MOE-5	6000KHz to 60MHz	+ .002% −10° to +60°C	Zero Trimmer	$35.00
MOE-10	6000KHz to 60MHz	+ .0005% −10° to +60°C	Zero Trimmer	$50.00

INTERNATIONAL
CRYSTAL MFG. CO., INC.
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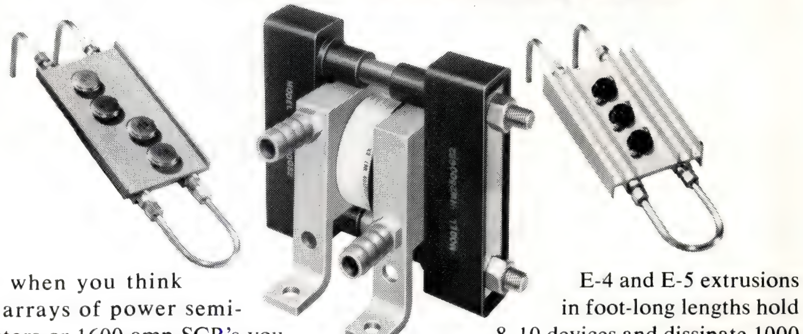
Circle No. 59

No. 22 of a Series

Quiet is the sound of our liquid cooled heat sinks for hot semi's

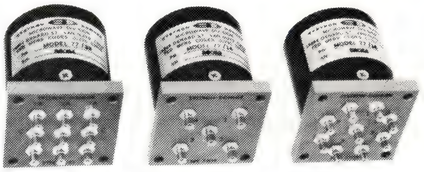


Today when you think about arrays of power semiconductors or 1600-amp SCR's you think liquid. Otherwise you won't be able to hear yourself think. Cooling 3000 watts in a cubic foot with air makes more racket than anyone can stand. Now IERC has the building blocks for liquid cooled systems to handle that power and you can use almost any liquid. For instance, our E-4 and E-5 extrusions in foot-long lengths hold 8-10 devices and dissipate 1000 watts. For hot shots like hockey pucks our liquid sinks dissipate 1000 watts with just 20°C case rise. Write for details and ask about our liquid cooled packaging for circuit modules, too. IERC, a subsidiary of Dynamics Corporation of America, 135 W. Magnolia Blvd., Burbank, Calif. 91502.

IERC DCA **Heat Sinks**

Circle No. 60

New Coaxial Switches For ATE



Systron-Donner's remotely programmable coaxial switches handle high-speed signal switching and multiplexing in 50 and 75 ohm systems. Choose from these 3 models:

Model Number	7714	7718	7732
Pole arrangement	1X4 (1P4T)	1X8 (1P8T)	3X2 (3P2T)
Rise time	<500ps	<1ns	<350ps
Transient aberrations (Pk - Pk, 1 ns step)	2%	2%	1%
Price	$130	$185	$165

For full details, call your Scientific Devices office or contact S-D at 10 Systron Drive, Concord, CA 94518. For immediate details, call our Quick Reaction line (415) 682-6471 collect.

SYSTRON DONNER

Circle No. 61

MONOLITHIC CRYSTAL FILTERS

the State of the Art

OF HIGHER THINGS . . .
By international convention, the VHF frequency range extends from 30 to 300 MHz. At 30 MHz a monolithic quartz crystal filter element is about .002 in. thick and typically .25 in. in diameter. Fragile? Yes indeed. Maybe that's why only a handful of manufacturers offer crystal filters in the VHF range. Of these few, one is head and shoulders above the rest. Needless to say, that's us. (If we weren't, we wouldn't be writing this ad). Our first monolithic—way back in 1966—had a center frequency of 112 MHz. We pioneered the VHF monolithic crystal filter. And we're still pioneering. We supply production quantities of VHF monolithics at frequencies to 175 MHz. No one else can make that statement, and believe us — we're pretty high on our product.

NOW FOR THE LOW-DOWN
Although we're mighty proud of our VHF Monolithic Crystal Filters, much of our bread and butter is earned at lower frequencies. As low as 3 MHz in special cases. And at 10.7 and 21.4 MHz, we offer the industry's widest selection of stock model monolithic crystal filters — over 50 models in all. We can help you with all your production requirements for monolithics. More and more people are saying our low down is on the up and up.

. . . AND WHAT TO DO WITH THEM
Our VHF Monolithics are used as front-end filters and as up-converter filters. They're found in satellites and in commercial equipment. In the U.S. and in most other major countries of the world. In VHF two-way radios, paging receivers, and HF receivers and transmitters. And in a variety of special applications, like spectrum clean-up in frequency synthesizers.

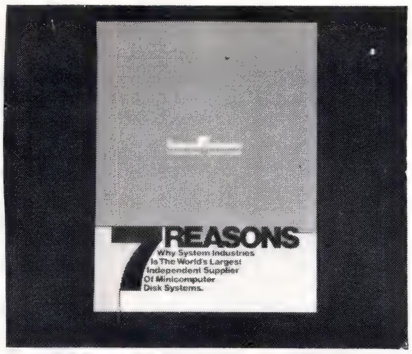
What's your application? Whether it's one of the above or something brand-new we'll be glad to work with you. Just give us a call, or a brief note outlining your requirements. We'll take it from there.

Pii

Piezo Technology Inc.
2400 Diversified Way Orlando, Florida 32804
305-425-1574
The Standard in monolithic crystal filters.

Circle No. 62

LITERATURE


7 REASONS
Why System Industries Is The World's Largest Independent Supplier Of Minicomputer Disk Systems.

MINICOMPUTER DISC SYSTEMS. The brochure describes a line of ready-to-use disc storage systems for minicomputers. It details storage specifications for both the Series 3500/4500 lines which employ Diablo disc drives, and the Series 9500 system which uses the new CDC 9760/62 disc drives. System Industries, 535 Del Rey Ave., Sunnyvale, CA 94086. **226**

POWER SEMICONDUCTORS. The "Power Semiconductor D.A.T.A. Book" is a 370-pg. reference to more than 25,000 high current power semiconductors of the world. Electrical and physical characteristics of power rectifiers, transistors, SCR's and triacs appear in 13 application-oriented sections. Published twice/yr., price is $47.50. D.A.T.A. Inc., 32 Lincoln Ave., Orange, NJ 07050. **227**

LIT MATES TELL ALL. A 100-pg. systems design manual with a 6-pg. technical sales brochure provide all you need to know about the Series AN5800 completely integrated computer-compatible data conversion systems. The manual includes design information charts, drawings and call-out photos. A reply card is provided for obtaining prompt technical assistance and quotation. Analogic, Audubon Rd., Wakefield, MA 01880. **228**

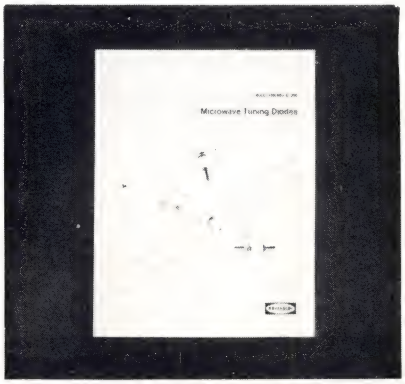
FAN/BLOWER RELIABILITY. Reducing the voltage to eliminate noise in fans and blowers used for cooling electronic devices and circuits, can adversely affect equipment lifetime. It also will undermine reliability and decrease performance, according to this bulletin. Several graphs show how reductions affect both torque and speed. Rotron Inc., Woodstock, NY 12498. **229**

GC/MS DATA PROCESSORS. Three comprehensive booklets describe the hardware, software, specs and operation of gas chromatograph/mass spectrometer (GC/MS) data processors. GC/MS instruments discussed include quadrupole, magnetic and time-of-flight types. Specify, on letterhead, the instruments of interest. System Industries, 535 Del Rey Ave., Sunnyvale, CA 94086. **INQUIRE DIRECT.**

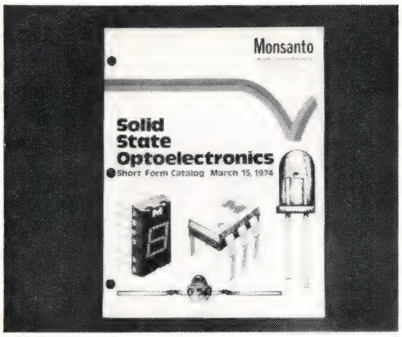
CARTRIDGE DISC SYSTEM. Description and specs for a multi-drive cartridge disc system (DD-15) designed to interface with DEC's PDP-11 and 8E; Interdata's 50, 70, 80, 7/16 and 7/32; Data General Nova Series; and DCC-116 minicomputers are contained in a 2-pg. data sheet. DIVA, Inc., 607 Industrial Way W., Eatontown, NJ 07724. **230**

POWER SUPPLIES. To assist in selecting the proper power supply and applying it to a system, the "Power Supply Selection Guide" contains charts and graphs on a variety of useful applications and parameters. A colorful 15×22-in. wall chart, it lists general information, selection guides and application considerations. ACDC Electronics, Inc., Oceanside Industrial Center, Oceanside, CA 92054. **231**

"TESTING NEWS AND VIEWS" discusses news, problems and current areas of interest in the testing industry. It keeps readers informed of recent federal, state and municipal health and safety regulations and implications, as well as innovations at ATL labs. The 4-pg. bulletin is published monthly. Associated Testing Laboratories, Inc., 9 Brighton Rd., Clifton, NJ 07012. **232**



MICROWAVE TUNING DIODES. Package styles, electrical characteristics and max. temperature ratings of these diodes are described in this colorful bulletin. Raytheon Co., 130 Second Ave., Waltham, MA 02154. **233**


Monsanto
Solid State Optoelectronics
Short Form Catalog March 15, 1974

OPTOELECTRONICS. The short-form catalog itemizes many products in Monsanto's lines of LED displays, discrete indicators, optoisolators and solid-state relays. It includes electrical and optical characteristics and full mechanical data on the products. Monsanto Co., 3400 Hillview Ave., Palo Alto, CA 94304. **234**

THICK-FILM MATERIALS. A 6-pg. brochure describes standard thick-film resistor, conductor, dielectric and insulating ink compositions. Also included are such compatible screen-printable products as epoxy cements, solder pastes and various optoelectronic materials. All products are categorized, described and listed. Electro Materials Corp. of America, 605 Center Ave., Mamaroneck, NY 10543. **235**

DISC DRIVE SYSTEM FOR MINIS. This 4-pg. brochure describes, illustrates, and gives specs for the 116 Mbytes/spindle DIVA COMPUTROLLER™ I. The brochure is most relevant to users of DEC, Interdata, Data General and TI minis. DIVA, Inc., 607 Industrial Way W., Eatontown, NJ 07724. **236**

DIGITAL MULTIMETER. Model 134, a 3-1/2 digit multimeter, is fully described in this 4-pg. brochure. All information on the model, which is currently the least expensive full-range digital multimeter on the market, is detailed. Data Precision Corp., Audubon Rd., Wakefield, MA 01880. **237**

FET ANALOG SWITCHES in several sample-and-hold circuits are described in app note AN74-2. The paper is intended to circumvent the "cut-and-try" methods used by many designers of these circuits, and presents analytical design criteria and practical circuits. Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054. **238**

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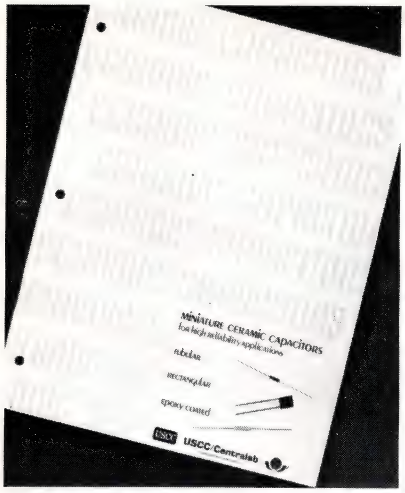
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HI-REL CERAMIC CAPACITORS, and their use in high reliability applications, are the subject of this 20-pg., 4-color catalog. High-reliability testing procedures, inspection criteria, complete specs—plus mechanical and environmental characteristics of the capacitors—are listed. U. S. Capacitor Corp., 2151 N. Lincoln St., Burbank, CA 91504. **212**

CRT YOKES AND COILS. A 6-pg. product index lists a wide range of precision CRT deflection yokes, focus coils, accessory coils, rotating yokes and mechanical accessories for CRT displays. Important operating characteristics are charted and recommended applications are indicated for each component listed. Syntronic Instruments, Inc., 100 Industrial Rd., Addison IL 60101. **213**

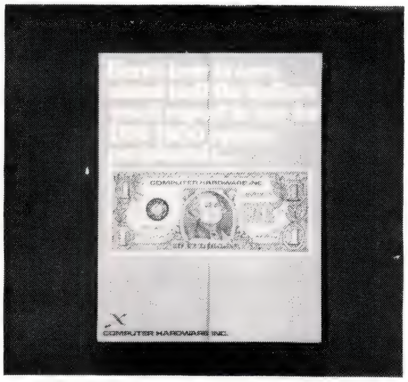
TRANSISTOR TESTING. System app note 113 describes the T397 test instrument used for testing high-voltage npn transistors at voltages up to 2500V. It also shows how the T397 can use an automatic handler and special binning techniques. Teradyne, Inc., 183 Essex St., Boston MA 02111. **214**

CERAMIC CAPACITORS. The 16-pg., 4-color brochure discusses monolithic ceramic capacitors for high-volume applications. Complete specs and characteristics are listed and handy cross-reference matrices are included. U. S. Capacitor Corp., 2151 N. Lincoln St., Burbank CA 91504. **215**

WIRE WOUND RESISTORS. A completely revised 32-pg. handbook of precision and wire wound resistors includes a military-style ordering guide and cross reference chart, information on established reliability devices, a technical guide on resistance temperature characteristics, plus information on nearly 200 types of wire-wound resistors. RCL Electronics, 700 S. 21st St., Irvington, NJ 07111. **216**

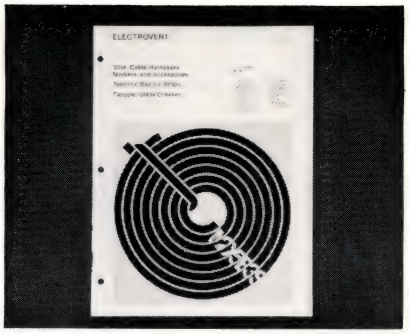
SMALL HOLE DRILLING. "Diamond Drills and Equipment for Small-Hole Drilling in Glass and Ceramics" is a technical report explaining the techniques required to drill precision holes through hard and brittle materials. Included are descriptions of machines and of drills ranging in size from 0.001 to 0.500-in. O. D. Lunzer Industrial Diamonds, Inc., 48 W. 48th St., New York, NY 10036. **217**

SCR POWER CONTROLLERS. Condensed product bulletin No. 100A provides the data needed to specify the proper SCR power controller. Included in the 8 pgs. are details of SCR firing devices, a comparison of ON-OFF and proportional control modes, performance options, connection diagrams and output waveforms. Vectrol, Inc., 1010 Westmore Ave.,Rockville, MD 20850. **218**



IBM 1800 PERIPHERALS. Saving money on IBM 1800 peripherals is stressed in a brochure presenting the CHI-1103 600-lpm printer and the CHI-1106/C add-on core memory systems. Computer Hardware Inc., Box 4496, Sacramento, CA 95825. **219**

IC CHIP SET. App note 74-1 covers a number of methods for constructing analog-to-digital converter systems, using the LD110/LD111 IC chip set. The 12-pg. note also provides a basis for criteria in selecting system components. Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054. **220**



WIRE/CABLE HARNESSES, MARKERS, ducts and accessory products are described in this revised 16-pg. brochure. The differences and application advantages of the products are fully explained. This illustrated brochure is designed to serve as a short-form, comprehensive source for ordering and quick reference. Electrovert, Inc., 86 Hartford Ave., Mt. Vernon, NY 10553. **221**

WIRE AND CABLES. The 4-color, 25 pg. brochure contains descriptions, engineering data and specs for the "Mini-Noise" coaxial, micromini coaxial and twin axial cable, and special hook-up wire. Descriptions and engineering data are also provided for MIL-C-17RF coaxial cable and "Micro-Cell" F110 coaxial cable. Malco, 5150 W. Roosevelt Rd., Chicago, IL 60650. **222**

HIGH-SPEED LOGIC FAMILIES. An engineering comparison study defines and evaluates many of the points of comparison that should be considered when selecting a logic family to use in a high-speed system or subsystem. The logic types detailed in the report are MECL 10,000 and high-speed Schottky TTL. Motorola, Inc., Box 20912, Phoenix, AZ 85036. **223**

SOLID STATE RELAYS of 3 basic types—contact closure control, solid-state control and hybrid control—are described in this bulletin. Charts, diagrams and graphs give easy reference. Grayhill, Inc., 561 Hillgrove Ave., La Grange, IL 60525. **224**

PRODUCT-LINE CATALOG. Data communications maintenance and signal interface equipment are outlined. Included are descriptions of a network control system and the data maintenance master. Atlantic Research Corp., 5390 Cherokee Ave., Alexandria, VA 22314. **225**

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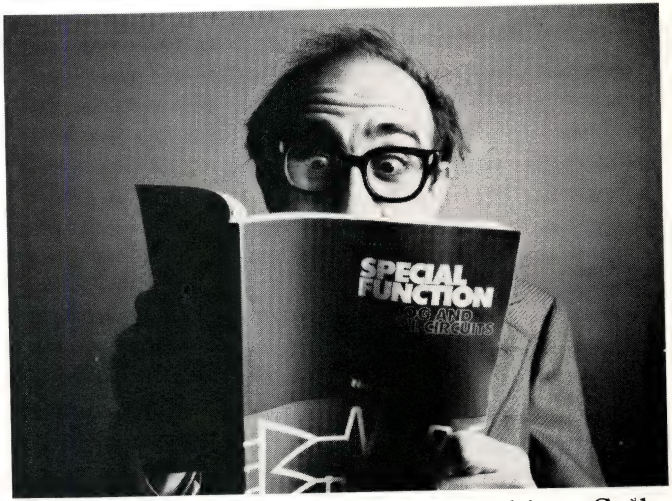

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signals and noise

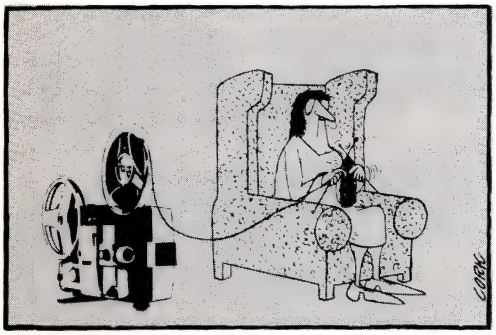
How small is small?

Dear Sir:

I enjoyed your news story on the Keyes paper, "How much smaller can digital IC's be made?" (EDN, March 5, 1974.) I think Keyes is too pessimistic; for example, our 9LS low-power Schottky line (formally introduced April 15) at 2 mW and 5 nsec breaks his "barrier" with a low-cost IC line using relatively simple processing. With more exotic techniques such as Isoplanar, one can reach 28 pJ on 700 psec ECL gates with on-chip power of 5 pJ at 700 psec.

I always enjoy EDN, keep up the good work.

Regards,
Rob Walker
Product Planning Manager
Digital Products Group
Fairchild Semiconductor
Mt. View, CA 94040



Standardizing standards?

Dear Mr. Bond:

I wish to express my appreciation for your article, "Computer-controlled instruments challenge designer's ingenuity," in the March 5, 1974 issue of EDN. I think there is a significant need to get the entire engineering community on board with current standards activities.

However, I would like to take issue with some of the concepts presented in the article. KineticSystems is a manufacturer of CAMAC equipment for process control and is successfully selling that equipment to the process control market. Our prices are competitive on a per system basis, not 2 or 3 times more expensive, as your article states.

Also, I feel that care should be taken in the use of the word standardized. CAMAC is a standardized system. You can currently buy over 1000 compatible CAMAC devices from over 60 manufacturers. Computer Products' RTP system is not standard in this sense, it is a proprietary system.

It's a long way from a one-company proprietary design to a broadly accepted standard such as CAMAC. It takes years of time and hundreds of thousands of dollars.

I would recommend that you give CAMAC another look as the most effective and the only standardized approach to computer-based process control.

Sincerely yours,
Lowell A. Klaisner
Vice President of Marketing
KineticSystems
Maryknoll Dr.
Lockport, IL 60441

Ed. Note: As Mr. Klaisner points out, CAMAC is the only worldwide standard now available for large instrumentation systems. Because of this, it is likely that some version of it will eventually be accepted as a process control standard. That makes it imperative that valid objections to CAMAC be recognized and dealt with. The article attempted to show some of these objections.

It was never our intent to proclaim RTP a standard when it is, as noted, a proprietary system. It happens that RTP is very "CAMAC-like" in conception, but simplified; it provided a good example of what CAMAC should be more like if it is to be an acceptable standard for process control.

As for the price being 2 to 3 times as expensive, my information comes from published price lists. Let me give you an example: A Computer Products RTP I/O Expander for PDP-11 costs $900. PCS of Flint, MI also makes a complete interface system for process control. Their PDP-11 interface is $1100. KineticSystem's equivalent interface, a CAMAC PDP-11 branch driver, is $2645. In addition to that, a PDP-11 crate controller is required to complete the interface. It costs $1350. Even without the crate controller, the price is not really competitive. It's time that the faults as well as the virtues of CAMAC were discussed. My article was only a small step in that direction.—JB

Author acknowledges error

Dear Sir:

Thanks to Mr. Graeme for correcting my error in the design article, "Clamp fast pulses with one component."

His solution for total capacitance is correct for initial conditions, but for recurrent pulses the TC zener provides a significant reduction in capacitive loading, contrasted to the zener diode. The large zener capacitance is charged through the forward-biased diode during a positive transition of V_S. When V_S goes negative with respect to the zener capacitance voltage, this junction becomes reverse biased and remains so until V_S becomes more positive than this voltage. Thus, the total effective capacitance for subsequent pulses is greatly reduced.

My apology for not including this in the original article.

Sincerely,
Wes Walloch

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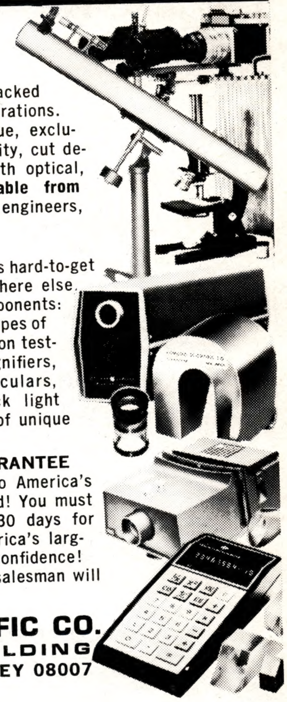

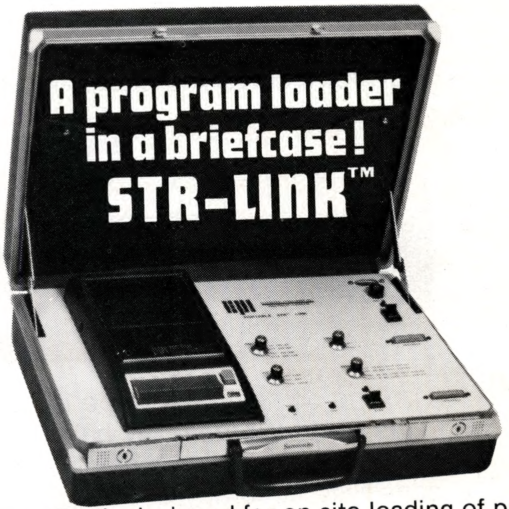

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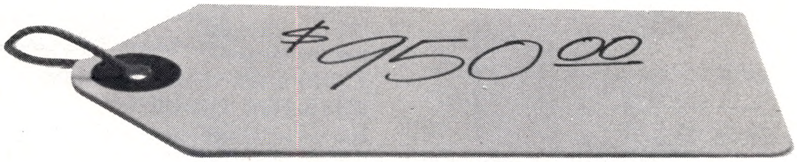

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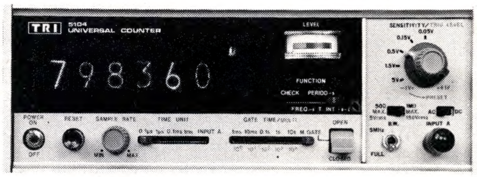
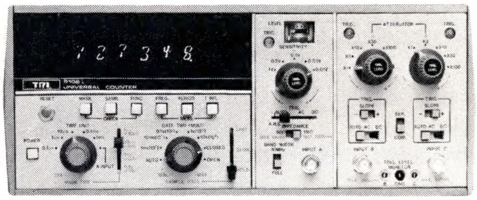
However, if your needs run along the line of universal counters, look to our 5104 and 5106 models. *The 5104* has a frequency range to 50MHz, and is sensitive to 50mVrms.



It measures time interval, period, totalizes events and has a price tag of $590.00. *The 5106* has a higher range: 70MHz. A better sensitivity: 10mVrms. It measures both chattering and burst mode signals. It costs $1250.00.



T.R.I. is a company which represents two decades of progress in digital test equipment, instruments and pricing.

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505 West Olive Avenue, Sunnyvale, CA 94086
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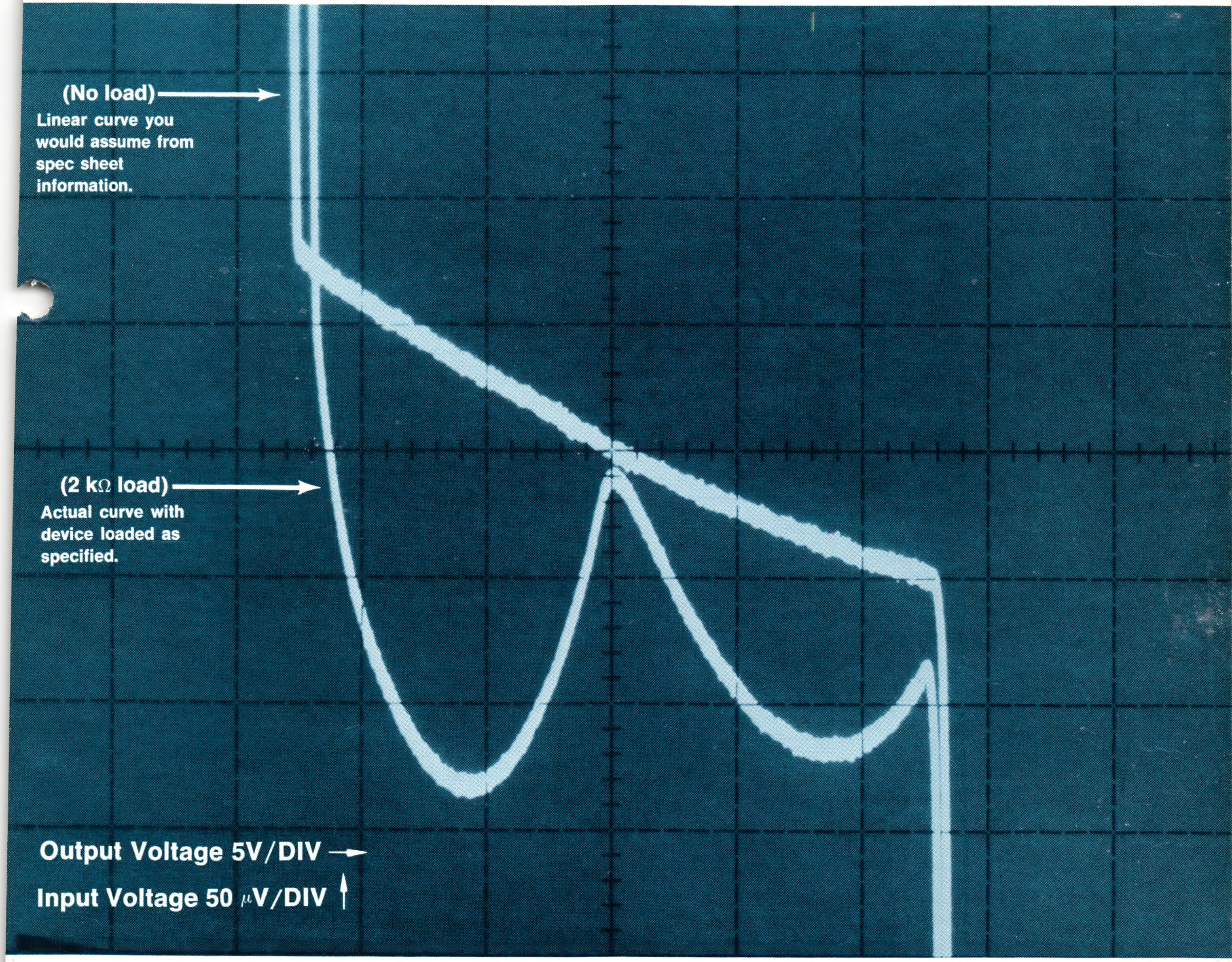
Circle No. 69

The spec sheets tell you what should happen.



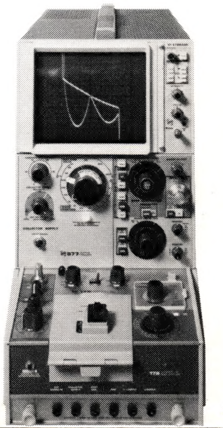
The 577 shows you what did.

When you're designing circuits using linear IC's, you count on spec sheets for the information you need. Generally, gain, CMRR and power supply rejection ratio are given as the ratios of voltage changes measured between discrete points. You assume a "linear" integrated circuit has a linear gain curve (a straight line) with no spurious excursions. But an actual device operating in real-life conditions isn't always linear. Often it produces very irregular curves that may make a big difference in your finished circuit.

These irregular curves are hidden from meters, digital read-outs and go no-go indicators. In fact, a Curve Tracer with its CRT display is the only way to see what is actually happening across the entire operating range of the device you're testing.

The Tektronix 577/178 Curve Tracer will measure and display gain. Offset voltage. Input bias current. Common-mode rejection ratio. And power supply rejection ratio. In addition, the 577/178 displays thermal effects. Popcorn (or flicker) noise. And parameter nonlinearities. And the 577/178 has a storage display to retain curves for comparison or detailed evaluation. Yet it costs only $3100.

To learn about the pitfalls of linear IC performance and measurements write to Tektronix for pamphlet No. A3040.
Tektronix, Inc., P.O. Box 500,
Beaverton, Oregon 97005.
Or call your local field engineer.



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